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MAGIC II: AN AUTOMATED GENERAL PURPOSE SYSTEM FOR STRUCTURAL ANALYSIS

VOLUME II: USER'S MANUAL

STEPHEN JORDAN
A. MICHAEL GALLO
BELL AEROSPACE COMPANY

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MAGIC II: AN AUTOMATED GENERAL PURPOSE SYSTEM FOR STRUCTURAL ANALYSIS

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FOREWORD

This report was prepared by Textron's Bell Aerospace Company (BAC), Buffalo, New York under USAF Contract No. F-33615-69-C-1241. This contract is an extension of previous work initiated under Project No. 1467, "Structural Analysis Methods," Task No. 146702, "Thermal Elastic Analysis Methods". The program was administered by the Air Force Flight Dynamics Laboratory (AFFDL), under the cognizance of Mr. G.E. Maddux, AFFDL Program Manager. The program was carried out by the Structural Systems Department, Bell Aerospace Company during the period 2 December 1968 to 2 December 1970 under the direction of Mr. Stephen Jordan, BAC Program Manager.

This report, "MAGIC II: An Automated General Purpose System for Structural Analysis", is published in three volumes, "Volume I: Engineer's Manual", "Volume II: User's Manual", and "Volume III: Programmer's Manual". The manuscript for Volume II was released by the authors in January 1971 for publication as an AFFDL Technical Report.

The authors wish to express appreciation to colleagues in the Advanced Structural Design Technology Section of the Structural Systems Department for their individually significant, and collectively indispensible, contributions to this effort.

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This technical report has been reviewed and is approved.

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13. ABSTRACT

An automated general purpose system for analysis is presented. This system, identified by the acronym "MAGIC II" for Matrix Analysis via Generative and Interpretive Computations, is an extension of structural analysis capability available in the initial MAGIC System. MAGIC provides a powerful framework for implementation of the finite element analysis technology and provides diversified capability for displacement, stress, vibration and stability analyses.

The matrix displacement method of analysis based upon finite element idealization is employed throughout. Ten versatile finite elements are incorporated in the finite element library. These are frame, shear panel, triangular cross-section ring, trapezoidal cross-section ring (and core), toroidal thin shell ring (and shell cap), quadrilateral thin shell and triangular thin shell elements. Additional elements include a frame element, quadrilateral plate and triangular plate elements which can be used for both stress and stability analysis. The finite elements listed include matrices for stiffness, mass, incremental stiffness prestrain load, thermal load, distributed mechanical load and stress.

Documentation of the MAGIC System is presented in three parts; namely, Volume I, Engineer's Manual, Volume II: User's Manual and Volume III: Programmer's Manual The subject Volume, Volume III, is designed to facilitate implementation, operation, modification and extension of the MAGIC System.

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ABSTRACT

An automated general purpose system for analysis is presented. This system, identified by the acronym "MAGIC II" for Matrix Analysis via Generative and Interpretive Computations, is an extension of structural analysis capability available in the initial MAGIC System. MAGIC provides a powerful framework for implementation of the finite element analysis technology and provides diversified capability for displacement, stress, vibration and stability analyses.

The matrix displacement method of analysis based upon finite element idealization is employed throughout. Ten versatile finite elements are incorporated in the finite element library. These are frame, shear panel, triangular cross-section ring, trapezoidal cross-section ring (and core), toroidal thin shell ring (and shell cap), quadrilateral thin shell and triangular thin shell elements. Additional elements include a frame element, quadrilateral plate and triangular plate elements which can be used for both stress and stability analysis. The finite elements listed include matrices for stiffness, mass, incremental stiffness, prestrain load, thermal load, distributed mechanical load and stress.

The MAGIC II System for structural analysis is presented as an integral part of the overall design cycle. Considerations in this regard include, among other things, preprinted input data forms, automated data generation, data confirmation features, restart options, automated output data reduction and readable output displays.

Documentation of the MAGIC II System is presented in three parts; namely, Volume I: Engineer's Manual, Volume II: User's Manual and Volume III: Programmer's Manual. The subject document, Volume II, contains instructions for the preparation of input data and interpretation of output data.

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SECTION I

INTRODUCTION

The MAGIC II Systems for Structural Analysis is a logical extension of the original MAGIC System reported in References 1, 2 and 3. All capabilities available from the original MAGIC System have been retained. Extension of the program capability is primarily in the following areas.

(a) The implementation of four additional finite element representations and their associated element matrices.

(b) The improvement of output displays to facilitate ease of interpretation by the User.

(c) The provision of an "Agendum Library" to accommodate the following classes of analyses:

 (1) Statics

 (2) Statics with Condensation

 (3) Statics with Prescribed Displacements

 (4) Stability

 (5) Dynamics (Modes and Frequencies)

 (6) Dynamics (with Condensation)

(d) The addition of an out-of-core eigenvalue routine for non-symmetric matrices based on the power method "on the order of" 3000 x 3000.

(e) The addition of improved and expanded error diagnostics.

(f) The addition of a prescribed displacement option to accommodate more than one load condition per execution.

(g) The addition of the capability to accept either rectangular, cylindrical or spherical coordinates as input data.

(h) The addition of miscellaneous arithmetic modules to the System to support the computational procedures.

(i) The addition of a new assembly module to increase the permissible assembled system matrix size.

Numerous other extensions have been provided with the MAGIC II System. These extensions will be delineated in detail in the Sections to follow.

The MAGIC II System is made up of three primary functional elements; namely, Preprocessor, Execution and Structural Monitors. The organizational interrelation of these monitors is considered in Volumes I and III of this report (References 4, 5). Of interest here are the interfaces of these monitors with the MAGIC System User.

The Preprocessor Monitor relies wholly upon the FORMAT System for its capability. This Monitor has the responsibility for reading and interpreting FORMAT data, setting system parameters, allocating available internal and external storage, and translating the input abstraction instructions into a form useable by the Execution Monitor. Under normal operation of the MAGIC System for structural analysis, User provided data to the Preprocessor Monitor consists of a preset control deck. On the other hand, nonstandard operation of the MAGIC System to perform matrix algebra requires development of a complete problem oriented control deck for the Preprocessor Monitor.

The Execution Monitor carries out instructions passed from the Preprocessor Monitor and has no interfaces with the MAGIC System User. The primary input data interface resides in the Structural Monitor. Modules underlying the Structural Monitor, read, interpret, and store the structure input, generate the requested matrices and furnish these matrices in a form useable by the Executive Monitor.

Corresponding to the computational flow through the MAGIC System, Section II of this report begins with a description of the general arrangement of the MAGIC II System and continues with a description of the options available to the user via the available abstraction instructions. Attention is then focused upon the structural data. Preprinted input data sheets are described that facilitate the specification of structural data.

Section III is devoted to interpretation of the output from the MAGIC II System. Print options which provide precise User oriented output are enumerated by reference to specific example problems. These examples utilize each of the finite elements which comprise the MAGIC II System element library.

SECTION II

INPUT TO THE MAGIC II SYSTEM

A. INTRODUCTION

The MAGIC II System presents two input data interfaces to the Structural Analyst. The first encountered is referred to as the System Input Data interface. The System data instructs the program as to what operations should be performed during any execution. These operations may be viewed as the interpretive portion of the MAGIC System. For example, the matrix abstraction instructions which are required to perform a structural analysis are System Input Data. These instructions along with all other System options available to the User will be discussed in detail in the next section.

The second input data interface with the User concerns the Structural Input Data. For example grid point coordinates and boundary condition information are viewed as Structural Input Data. This problem oriented data accounts for nearly all the effort expended in conducting structural analyses.

Separate subsections, devoted to instructions for the specification of System and Structural Input Data follow utilization of both types of data is covered in depth. An in depth description of detailed instructions on carrying out general matrix computations is presented in Reference 6. Options frequently used in the MAGIC II System are clearly delineated in the next section.

B. SYSTEM INPUT DATA

1. General Description

The general arrangement of the MAGIC II digital computer program system is shown in Figure II-a. The supervisory program consists of the FORMAT control and two monitors; the Preprocessor Monitor, and the Execution Monitor. The main program controls the normal two phase operation by delegating control, in turn, to the two monitors.

The preprocessor Monitor directs the processing of card input data describing the machine configuration, the problem specification, the abstraction instruction sequence and the matrix data.

A standard, modified standard, or totally new machine configuration may be defined for each MAGIC II case.

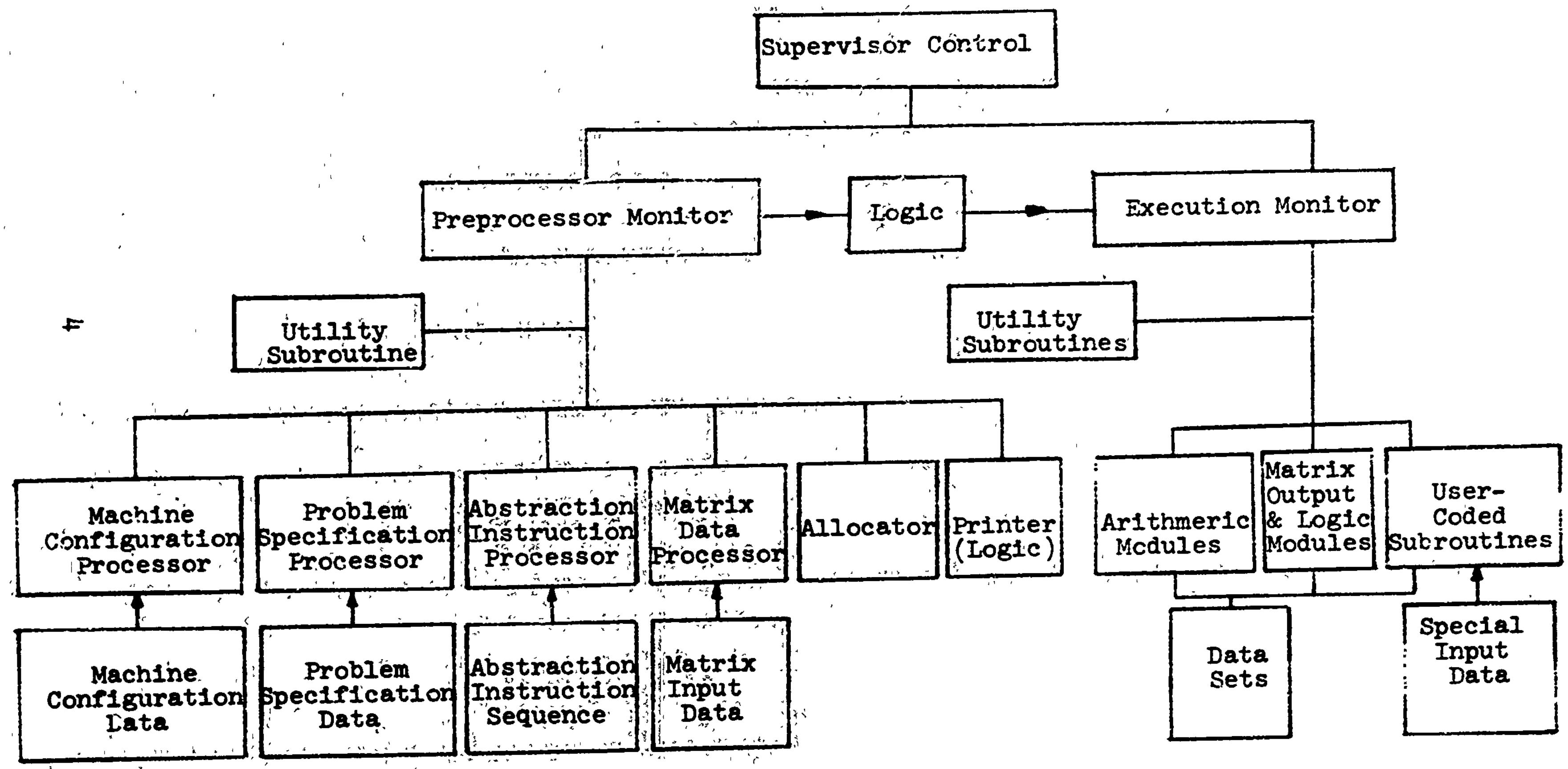

Figure II-a MAGIC II - Digital Computer Program

General output format and labeling information, and identifying names of the master input and output data sets (tapes) constitute the problem specification data.

The matrix and pseudo-matrix operations are input in the required sequence of execution in the abstraction instruction sequence. Abstraction instructions are submitted in free form on standard Fortran coding sheets for punched card reproduction.

Card input matrix data are specified on a standard form. Matrices may be of order 3000x3000, and may contain up to 6000 randomly ordered, single precision real elements, using 45600 words of storage on an IBM 360/65 Digital Computer.

For the general case, preprocessing involves straightforward sequential processing of data by each of the modules under the Preprocessor Monitor. Special preprocessing can be specified by proper use of the control cards described in Section II.B.2.

The final preprocessor operation is to pre-plan the data storage allocation through the problem and to record this program of the "complete problem solution logic" for use by the Execution Monitor.

The Execution Monitor directs the processing of data by the various operational modules according to the program prepared by the Preprocessor Monitor.

The standard matrix operational modules provide for matrix addition, subtraction, multiplication, and transpose multiplication, with optional concurrent scaling, and for matrix scalar multiplication, transposition, adjoining, dejoining, and inversion. Modules for the solution of simultaneous equations by elimination and iterative techniques complete the basic standard matrix operation capability of the system.

The pseudo-matrix operational modules provide for the element by element multiplication of two matrices of identical order, the elements of a matrix to be raised to a scalar power, the extraction of the algebraic maximum and minimum elements of the rows or columns of a matrix (i.e., the envelope of a matrix), the diagonalization of a row or column matrix, the generating of null and identity matrices, and the renaming of a matrix. Included in the classification of pseudo-matrix operational modules is the "Structure Cutter" subroutine which generates a well conditioned solution of "n" linear simultaneous equations in "m" unknowns by Jordanian elimination (where $n \leq m$).

Matrices produced as the results of standard and pseudo-matrix operations may be as large as 3000x3000 witn no restriction on population density. Storage of matrix data is by column sort, and when individual column population density is less than 50 percent, storage is in compressed format. In compressed format, each non-zero element and its corresponding row location are sequentially stored, and zero elements are omitted. Where feasible, the subroutines operate directly on the compressed data.

MAGIC II includes two subroutines for the calculation of eigenvalues. The first subroutine calculates the specified number of eigenvalues, beginning with the largest, and the corresponding eigenvalues of a matrix, whose maximum order is limited by the working core storage available to the subroutine. Typically, with a 32K storage unit, the matrix may be as large at 160 x 160. This subroutine is written for a real symmetric matrices only. The second subroutine also calculates the specified number of eigenvalues and eigenvectors beginning with the largest eigenvector. However, the real eigenmatrix can be symmetric or nonsymmetric and the only limit on its order is the amount of working storage available to the MAGIC system. For example, with a 32K storage unit, the matrix may be as large as 2000 x 2000.

Up to nine special operational subroutines can be coded by the user and added to the system. The fourth user coded module is the structural generative system of MAGIC and will be described in Section II.B.2.d.

The sequence of operation is controlled by simple abstraction instructions prepared by the user, keypunched, and read directly by the machine. Comments may be included in the abstraction instruction sequence for explanation of the results.

Limited logic is available in the form of a conditional transfer. A matrix may be tested for nullity and, if true, control will be transferred forward to a specified abstraction instruction in the sequence. Conditional transfer is limited to a "skip ahead" in the abstraction instruction sequence.

Matrices can be printed in a standard form, with small number suppression and row-column labeling. The matrix elements are printed as floating point numbers with optional exponent.

The normal printed output for a MAGIC II case includes a listing produced by the preprocessor. The listing unconditionally includes all control and specification data together with the complete abstraction instruction sequence. The listing will also include matrix input data, special input data, and the machine generated "complete problem solution logic" if the appropriate options are chosen in the control data.

2. INPUT DATA

a. Organization

The input data for a general case consist of control and specification data, the abstraction instruction sequence, and problem data. Control, machine configuration and problem specification data constitute the control and specification data. Matrix and special (non-matrix) data constitute the problem data. These data must be sequenced as follows.

(1) Machine configuration data

(2) Problem specification data

(3) Abstraction instruction sequence

(4) Matrix data

(5) Special data

where each section is preceded by a control card which indicates the beginning of and the options chosen for that section. The last section is followed by a control card indicating the end of all input to a MAGIC case. The typical deck set-up is shown in Figure II-b.

Columns 73 to 80 of all card input data are used for card handling purposes in keeping with normal MAGIC procedure.

b. Control and Specification Data

(1) Control Cards

The general format for control cards is as follows.

Card Column	Contents
1	$
2-15	Control card name, left justified
16-72	Variable field information (options)

The following are MAGIC control cards for the five sections of input data and the end of input data respectively: $MAGIC, $RUN, $INSTRUCTION, $MATRIX, $SPECIAL and $END.

Summary examples of code for the available control and specification data are shown in Table I.

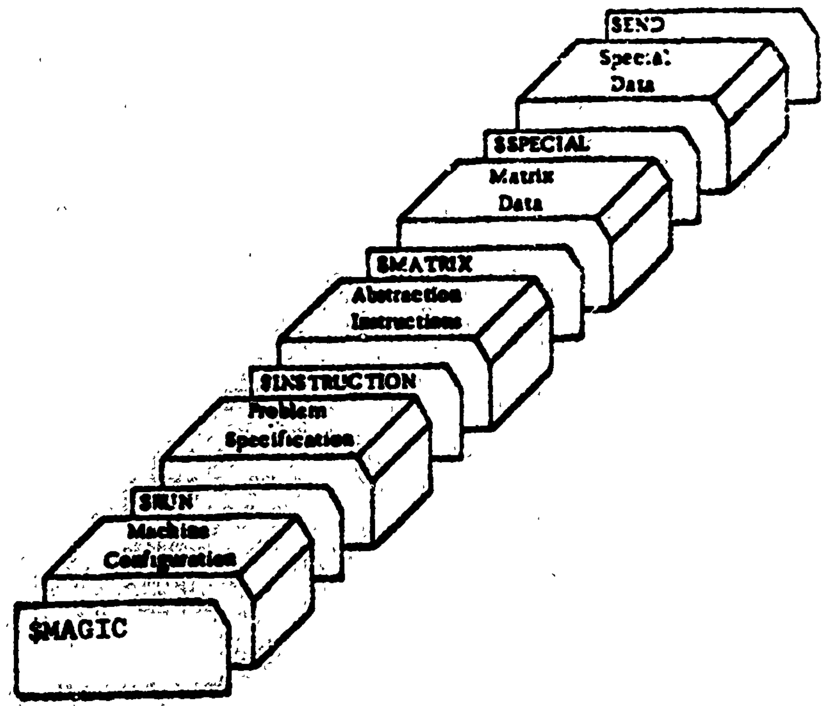

Figure II-b - Typical MAGIC II - Deck Set Up

TABLE I

EXAMPLE CODE FOR CONTROL AND SPECIFICATION DATA

```
CC1    CC7      CC16

C(COMMENT)

$MAGIC          STANDARD

                { GO , NOLOGIC
$RUN            {
                { NOGO , LOGIC
      ANALYSIS      ( ANALYSIS IDENTIFICATION )
      PROBLEM       ( PROBLEM IDENTIFICATION)
      INPUT TAPE    ( NAME, MODIF )
      OUTPUT TAPE   ( NAME, MODIF )
      PAGE SIZE     ( W * H )
$INSTRUCTION    { SOURCE
                { NOSOURCE

$MATRIX         { NOLIST , NOPRINT
                { LIST , PRINT

$SPECIAL        { NOLIST
                { LIST

$END
```

The $MAGIC card indicates the beginning of a MAGIC case and the options control the machine configuration that is used during the running of the case. The form of the card is:

1	16
$MAGIC	STANDARD

where the option available to the engineering user is:

STANDARD - the standard machine configuration is used for this run.

In the implementation of the MAGIC II System at any installation a standard logical machine configuration is compiled into the machine configuration processor module. This logically defines the data processing capability of the computing hardware at the particular installation and may require temporary modification due to day-to-day variations in the machine resources available. To this end options are provided on the MAGIC card to allow such temporary changes by the entry of appropriate machine configuration data cards (Reference 5). Modification of the standard configuration is properly a function of specialists in systems maintenance, and the STANDARD option will always be chosen, therefore, by the engineering user and may be omitted.

The $RUN card indicates the beginning of the problem specification data and the options control the manner in which the case is executed. The form of the card is:

1	16	
$RUN	{ GO ,	NOLOGIC
	NOGO ,	LOGIC

where the execution options are:

GO - the case is executed after it has been preprocessed.

NOGO - the case is not executed and the run is terminated after all preprocessing is complete.

NOTE: The underlined option is the default option and will be taken if no option is specified.

and the logic options are:

NOLOGIC - no listing of the problem solution logic is given.

LOGIC - a listing of the complete problem solution logic is given showing the complete sequence of instructions to be executed and the associated external storage allocation for the case. This is included as part of the preprocessor output.

The $INSTRUCTION card indicates the beginning of the abstraction instruction sequence and the options define the type of abstraction sequence which is entered. The form of the card is:

```
1             16

              ┌ SOURCE
$INSTRUCTION ┤
              └ NOSOURCE
```

where the options are:

SOURCE - the abstraction instruction sequence is card input.

NOSOURCE - (this option is provided for future development of a method of entry of frequently occurring abstraction sequences.)

The $MATRIX card indicates the beginning of the matrix data and the options define whether the matrix data is included in the preprocessor output. The form of the card is:

```
1          16

           ┌ NOLIST  ,     NOPRINT
$MATRIX    ┤
           └ LIST    ,     PRINT
```

where the options are:

NOLIST - the card images of the matrix data are not printed.

LIST - the card images of the matrix data are printed as they are read.

NOPRINT - the matrix data are not printed after sorting.

PRINT - the matrix data are printed after being sorted by row and column.

The $SPECIAL card indicates the beginning of the special (nonmatrix) data and the options define whether the special data is included in the preprocessor output. The form of the card is:

1	16
$SPECIAL	NOLIST
	LIST

where the options are:

NOLIST - the card images of the special data are not printed.

LIST - the card images of the special data are printed as they are read. This option applies only when the NOGO option is entered in the $RUN card.

The $END card indicates the end of all card input data to a FORMAT case. The form of the card is:

1	16	72
$END	(any variable text)	

The contents of the $END card are reproduced as the last line of printed output for a case.

The standard options on the control cards are shown underlined, and these are automatically selected if the option field is blank.

$MATRIX and $SPECIAL cards are required if matrix data and special data are submitted, respectively. All other control cards are unconditionally required.

(2) Machine Configuration Data Cards

The machine configuration data cards define the logical machine configuration used during the running of the case if the standard configuration is temporarily modified. No entries are made when the STANDARD option is entered on the $MAGIC control card.

(3) Problem Specification Data Cards

The problem specification data cards provide general output format and labeling information and identify the master input and output tapes that are used by the problem. The following are problem specification data cards: ANALYSIS, PROBLEM, INPUT TAPE, OUTPUT TAPE, and PAGE SIZE.

The ANALYSIS card provides labeling information for the listing of the abstraction instruction sequence and the listing of the problem solution logic. If the ANALYSIS card is omitted, a totally blank header is used. Only one ANALYSIS card per case is allowed. The form of the card is:

1	7	72
	ANALYSIS (variable text)	

The variable text is printed at the top of each page of the listing of the abstraction instruction sequence, and each page of the problem solution logic if the appropriate option is entered in the $RUN card. The text should identify the type and origin of the analysis under consideration.

The PROBLEM card provides labeling information for the output from the problem. If the PROBLEM card is omitted a totally blank header is used. Only one PROBLEM card per case is allowed. The form of the card is:

1	7	72
	PROBLEM (variable text)	

The variable text is printed at the top of each page which is produced as the results of the abstraction instruction sequence, and each page of matrix and special input data if the appropriate options are entered in the $MATRIX and the $SPECIAL and $RUN control cards respectively. The text should identify the specific problem under consideration.

The INPUT TAPE cards provide identification of the master input tapes used by the problem. If no INPUT TAPE cards are entered, the tapes normally assigned to this function are used as scratch tapes during execution. The form of the card is:

1	7
	INPUT TAPE (name, modif)

where the arguments are:

name - a six character alphameric name used to identify the master input tape.

modif - an integer number used as a modifier to the name (usually the date).

When master input tapes are used in a MAGIC case, the appropriate instruction for the machine operator to mount tapes must be made external to the normal card input.

The OUTPUT TAPE cards provide identification of the master output tapes used by the problem. If no OUTPUT TAPE cards are entered, the tapes normally assigned to this function are used as scratch tapes during execution. The form of the card is:

1 7

OUTPUT TAPE (name, modif)

where the arguments are:

name - a six character alphameric name used to identify the master output tape.

modif - an integer number used as a modifier to the name (usually the date).

When master output tapes are used in a MAGIC case, the appropriate instruction for the machine operator to save tapes must be made external to the normal card input.

The PAGE SIZE card indicates the limit on the size of the printed output which is produced as the results of the abstraction sequence. A standard print format of six lines per inch is used. If the PAGE SIZE card is omitted the standard limits of 14 inches by 11 inches are used. Only one PAGE SIZE card per case is allowed. The form of the card is:

1 7

PAGE SIZE (width * height)

where the arguments are:

width	-	the width in inches of the printed output.
height	-	the height in inches of the printed output.

Allowable page sizes for printed output are 14 * 11, 11 * 8 or 8 * 11 where only the integer part of the width or height dimension need be entered (i.e., 8 for 8.5).

Entry of the nonstandard limits on the PAGE SIZE card should be accompanied by an external instruction to the machine operator of the required output page size.

c. Abstraction Instruction Sequence

(1) General Format

Abstraction instructions are submitted in free form on standard FORTRAN coding sheets, (i.e. blanks are ignored).

The general format for an abstraction instruction is:

Card Column	Contents
1-5	A one to five (1-5) digit statement number.
7-72	An input/output, control or arithmetic statement.

The statement number is a unique index, and is required only for statements to which control can be transferred by a control statement.

Comments may be inserted in the sequence of abstraction instructions. Comments must have a C in card column 1 and any text in card columns 2-72. The only effect of a comment is that the text is printed in the printed listing of the abstraction instruction sequence.

The abstraction instructions are executed in the sequence in which they are submitted. Consequently, any matrix used in an abstraction instruction either must appear as the result of a previous abstraction instruction or must be input by card or tape.

A MAGIC matrix name consists of one to six (1-6) alphameric characters, the first of which must be alphabetic. When the matrix name is interpreted, all non-blank characters are left justified and the remainder of the word is filled with blanks.

A scalar is processed as an element of a matrix and is identified by the matrix name modified by subscripts, which respectively define the row and column location of the scalar in the matrix.

Summary examples of code for the available abstraction instructions are shown in Table II.

(2) Input/Output Statements

Two input/output statements are available: a matrix print statement which is used to print matrices in a standard form and a matrix save statement which is used to save matrices in a standard form on a physical tape for future use.

Matrix Print statements are of the form:

PRINT (a, b, c, d)e

where the arguments are:

a - a six character alphameric name which is printed as a label on the rows of the printed matrices e. The row label is ROW if a is blank.

b - a six character alphameric name which is printed as a label on the columns of the printed matrices e. The column label is COL if b is blank.

c - the element print code Ef or Ff. If the code is Ef, the matrix elements are printed as floating point values with exponent, with f decimal digits to the right of the decimal point. The value of f is an unsigned integer with the limitation 0 f 8. If the code is Ff, the matrix elements are printed as floating point values without exponent, with f decimal digits to the right of the decimal point. If c is blank, the matrix elements are printed by the element print code E6.

d - an unsigned floating point number, with or without exponent, bounding matrix element values that are trivial and not to be printed. That is, the matrix element aij is omitted from printing if $|aij|<d$. If d is blank, zero valued elements are omitted from printing.

TABLE II

EXAMPLE CODE FOR ABSTRACTION INSTRUCTIONS

```
CC1   5  7                                                              72
     101 PRINT (ROWNAM, COLNAM, ELCODE, CUTOFF)  MATNAM, (etc.)
     102 SAVE  (TAPNAM)  MATNAM,  (etc.)
     201 IF (MATNAM .NULL.) GO TO STATNO
     301 NAMEC   =  ±  NAMEA .ADD. ± NAMEB         .SCALE. ± NAMEF(I,J)
     302 NAMEC   =  ±  NAMEA .SUBT. ± NAMEB        .SCALE. ± NAMEF(I,J)
     303 NAMEC   =  ±  NAMEA .MULT. ± NAMEB        .SCALE. ± NAMEF(I,J)
     304 NAMEC   =  ±  NAMEA .TMULT. ± NAMEB       .SCALE. ± NAMEF(I,J)
     305 NAMEC   =  ±  NAMEA .EMULT. ± NAMEB       .SCALE. ± NAMEF(I,J)
     306 NAMEC   =  ±  NAMEA .SMULT. ± NAMEB(I,J)
     307 NAMEC   =  ±  NAMEA .TRANSP.
     308 NAMEC   =  ±  NAMEA .ADJOIN. ± NAMEB
     309 NAMEC   =  ±  NAMEA .POWER. ± NAMEB(I,J)
     310 NAMEC   =  ±  NAMEA .INVERS.
     311 NAMEC   =  ±  NAMEA .SEQEL. ± NAMEB
     312 NAMEC   =  ±  NAMEA .SEQIT. ± NAMEB, (MAXITR)
     313 NAMEC1, NAMEC2  =  ±  NAMEA .STRCUT. ± NAMEB, (CUTOFF, STOP, WTFACT)
     314 NAMEC1, NAMEC2  =  ±  NAMEA .EIGEN. (NUMEVS)
     315 NAMEC   =  ±  NAMEA .ENVROW.
     316 NAMEC   =  ±  NAMEA .ENVCOL.
     317 NAMEC   =  ±  NAMEA .DIAGON.
     318 NAMEC   =  ±  NAMEA .RENAME.
     319 NAMEC   =     NAMEA .IDENTC.
     320 NAMEC   =     NAMEA .IDENTR.
     321 NAMEC   =     NAMEA .NULL. NAMEB
     322 NAMEC   =     NAMEA .COLREP.NAME
     323 NAMEC1, NAMEC2  =  NAMEA .DEJOIN. (JPART, KODE)
     324 NAMEC1, NAMEC2  =  NAMEA .DEJOIN. (NAMEB(I,J), KODE)
     401 NAMEC1, (etc.)  =  ± NAMEA1, (etc.) .USER01. ± NAMEB1, (etc.)
```

c - a list of valid matrix names, separated by commas. The matrices identified in the list are printed when the matrix print statement is encountered.

Print instructions are executed as they occur in the sequence of abstraction instructions and consequently they should always appear after the generation of the relevant matrices, and immediately after such generation for optimum utilization of storage media during execution.

An example of the standard form of matrix printing is shown in Section II.3.b.

Matrix Save statements are of the form:

SAVE (a) b

where the arguments are:

a - a valid tape name that has been declared in the problem specification data.

b - a list of valid matrix names separated by commas. The matrices identified in the list are written on tape a as they are generated.

(3) Control Statements

A single control statement of limited scope is available. This is a conditional transfer statement which is used to "skip ahead" in the abstraction instruction sequence.

Conditional Transfer statements are of the form:

If (a .NULL.) GO TO b

where the arguments are:

a - a valid matrix name

b - the statement number to which control is transferred if matrix a is null. Transfer to b is limited to a "skip ahead" in the abstraction instruction sequence.

(4) Arithmetic Statements

The basic form for arithmetic statements is:

c = ± a .Op. ±b

where a and b are known matrix names, c is thename of the matrix to be computed, Op is the operation to be performed in computing c from a and b and the positive signs of a and b may be omitted.

Variations of this basic form are required for certain operations. These variations are described with the corresponding operational definitions when they occur in the following arithmetic statements.

Matrix Addition statements are of the form:

c = ± a .ADD. ±b .SCALE. ± f(i,j)

where the signed matrix b is added matrically to the signed matrix a, each element of the matrix sum is multiplied by the signed scalar f(i,j), and the matrix of scaled elements is named c.

The abbreviated form is:

c = ± a .ADD. ± b

where the scale is omitted.

Matrix Subtraction statements are of the form:

c = ± a .SUBT. ± b .SCALE. ± f(i,j)

where the signed matrix b is subtracted matrically from the signed matrix a, each element of the matrix difference is multiplied by the signed scalar f(i,j) and the matrix of scaled elements is named c.

The abbreviated form is:

c = ± a .SUBT. ± b

where the scale is omitted.

Matrix Multiplication statements are of the form:

c = ± a .MULT. ± b .SCALE. ± f(i,j)

where the signed matrix b is pre-multiplied matrically by the signed matrix a, each element of the product matrix is multiplied by the signed scalar f (i,j), and the matrix of scaled elements is named c.

The abbreviated form is:

c = ± a .MULT. ± b

where the scale is omitted.

Matrix Transpose-Multiplication statements are of the form:

c = ± a .TMULT. ± b .SCALE. ± f(i,j)

where the signed matrix b is pre-multiplied matrically by the transpose the signed matrix a, each element of the product matrix is multiplied by the signed scalar f(i,j), and the matrix of scaled elements is named c.

The abbreviated form is:

c = ± a .TMULT. ± b

where the scale is omitted.

Element-by-Element Multiplication statements are of the form:

c = ± a .EMULT. ± b .SCALE. ± f(i,j)

where each element of the signed matrix b is multiplied by the corresponding element of the signed matrix a, each element of the matrix of element products is multiplied by the signed scalar f(i,j), and the matrix of scaled elements is named c.

The abbreviated form is:

c = ± a .EMULT. ± b

where the scale is omitted.

Matrix-Scalar Multiplication statements are of the form:

c = ± a .SMULT. ± b(i,j)

where each element of the signed matrix a is multiplied by the signed scalar b(i,j), and the matrix of scaled elements is named c

Matrix Transposition statements are of the form:

c = ± a .TRANSP.

where the transpose of the signed matrix a is formed and named matrix c.

Matrix Adjoin statements are of the form:

c = ± a .ADJOIN. ± b

where the signed matrix b is adjoined to the signed matrix a and the resulting matrix is named c (i.e., c = [±a | ±b]).

Matrix Dejoin statements are of the form:

C_1, C_2 = A.DEJOIN.(b,d)

or

C_1, C_2 = A.DEJOIN.(B(i,j),d)

where the matrix (A(MxN) is dejoined, columnwise to form the two matrices C_1 (MxJ) and C_2 (Mx(N-J)) or dejoined row-wise to form the two matrices C_1 (JxN) and C_2 (M-J)x$_N$) where, $1 \le J < N$ is the partition number (i.e., $A=[C_1 \,\vdots\, C_2]$ the following definitions apply:

b - an integer specifying the row or column at which the matrix A is to be partitioned to form C_1 and C_2

B(i,j) - the element b_{ij} of matrix B specifies the row or column at which the matrix A is to be dejoined

d = o, for column dejoin
  = 1, for row dejoin

Matrix Column Repeat statements are of the form:

C = A .COLREP. B

where the column dimension of matrix B specifies the number of times the column matrix A is to be repeated to form the matrix C. If the dimension of A is (N x 1) and the dimension of B is (L x M) then the dimension of C will be (N x M).

Null Matrix statements are of the form:

C = A.NULL.B

Where a null matrix C is formed. C has a row dimension the same as the row dimension of matrix A and C has a column dimension the same as the column dimension of matrix B.

Identity Matrix statements are of the form:

B = A .IDENTC.

where B is an identity matrix having an order the same as the column dimension of matrix A (i.e., if A(MxL) then B(LxL) = I)

and

B = A .IDENTR.

where B is an identity matrix having an order the same as the row dimension of matrix A (i.e., if A(MxL) then B(MxM) = I)

Matrix Power statements are of the form:

c = ± a .POWER. ±b(i,j)

where the absolute value of each element of the matrix a is raised to the power of the signed scalar b(i,j) and the resulting matrix is given the sign of matrix a and named c .

Matrix Inversion statements are of the form:

c = ± a .INVERS.

where the inverse of the signed matrix a is formed by Jordanian elimination, and is named matrix c.

This subroutine unconditionally prints pivot element values, with column indices, as special output data.

Solution of Equations by Elimination statements are of the form:

c = ± a .SEQEL. ± b

where the solution, Y, of the system of "n" linear simultaneous equations in "n" unknowns, ± a Y = ±b, is formed by Jordanian elimination, and the solution matrix is named c.

This subroutine unconditionally prints pivot element values, with column indices, as special output data.

Solution of Equations by Iteration statements are of the form:

c = ± a .SEQIT. ±b, (d)

where the solution, Y, of the system of "n" linear simultaneous equations in "n" unknowns, ± aY = ±b, is formed by matrix iteration, and the solution matrix is named c. Execution is terminated when the number of iteration cycles is equal to d. This subroutine requires that the leading diagonal of matrix a dominates.

Eigenvalue - Eigenvector Extraction statements are of the form:

$$c_1, c_2 = \pm a \ .EIGEN. \ (d)$$

where d eigenvalues and the corresponding eigenvectors are extracted from the signed symmetric matrix a and named matrix c_1 and matrix c_2, respectively. The parameter d is an unsigned integer constant. Matrices c_1 and c_2 are of order (d x 1) and(n x d) respectively with a matrix a of order (n x n).

Eigenvalue - Eigenvector Extraction statements are of the form:

$$C_1, C_2, C_3, C_4 = A,B \ .EIGEN1. \ (d,e,f,g)$$

where d eigenvalues and the corresponding eigenvectors are extracted from the eigenmatrix A and named C_1 and C_2, respectively. With matrix A of order (NxN), matrix C is of order (dxl) and matrix C_2 is of order (Nxd). The following definitions apply:

A - Initial Eigenmatrix (N x N) real, input

B - Input guess for vectors (N x 2)
1st column is guess for eigencolumn vector
2nd column is guess for eigenrow vector

d - integer specifying the number of eigenvalues and vectors requested

e - If e = o, then 2nd column of B is not used
If e = 1, then 1st column of B is used and must be conveyed eigenvector corresponding to A

f - Integer specifying the number of iterations for each pass. There are 10 passes with the criteria updated each time for each eigenvalue calculation (CRIT = CRIT N + G). Default is 500 iterations.

g - Convergence criteria for eigenvalues and vectors. Default value is .001

C_1 - Output Eigenvalue Matrix (d x 1)

C_2 - Output eigen column vector matrix (N x d)

C_3 - Saved deflated eigen matrix for restart

C_4 - Saved vector matrix for restart (N x 2). First column in last iteration of last eigen column vector. Second column is last iteration of last eigen row vector.

NOTE FOR VECOUT AND MATOUT

A. If the first eigenvector column does not converge, then C_4 consists of 1st column - last iteration of the eigenvector (column) vector

2nd column - not used

C_3 consists of the original A eigenmatrix

Use e = 0 for restart with C_3 for A and C_4 for B

B. If the first eigen (row)vector does not converge or the eigen row root does not correspond to the eigen column root within the specified criteria*, then

C_4 consists of 1st column -converged eigen column vector
2nd column -last iteration of the eigen row vector

C_3 consists of the original A eigenmatrix

Use e = 1 for restart with C_3 for A and C_4 for B

*This case occurs only when there is more than one eigenvalue requested, since eigenrow convergence is only required for sweeping the eigenmatrix to prepare it for calculating the next eigenvalue.

C. If an intermediate or the last eigen (column) vector does not converge, then

C_4 consists of 1st column-last iteration of the eigen (column) vector
2nd column-converged eigenrow vector from the previously calculated eigenvalue

C_3 consists of the swept eigenmatrix used for calculating the unconverged column vector

Use e = 0 for restart with C_3 for A and C_4 for B

D. If an intermediate or the last eigen (row) vector does not converge or its root does not converge to the column root, then C_4 consists of

1st column - converged eigen column vector

2nd column - last iteration of eigen (row) vector

C_3 consists of the swept eigenmatrix used for calculating the converged eigen (col) vector

Use e = 1 for restart with C_3 for A and C_4 for B

E. If the last eigen (column) vector converges, then C_4 consists of

1st column - converged eigen (column) vector

2nd column - converged eigen (row) vector from the previously calculated eigenvalue

C_3 consists of the swept eigen matrix used for calculating the converged eigen (col) vector

Use e = 0 for restart with C_3 for A and C_4 for B

Matrix Envelope statements are of the form:

c = ± a .ENVROW.

or c = ± a .ENVCOL.

where the algebraic maximum and minimum values in each row (or column) of the signed matrix a are found, and the matrix of the extreme values is named c. The maximum values occupy the first column (or row) of matrix c respectively.

Matrix Diagonalization statements are of the form:

c = ± a .DIAGON.

where a diagonal matrix is formed from the signed column (or row) matrix a and named c. The elements on the diagonal of c are the corresponding elements of matrix a.

Matrix Rename statements are of the form:

c = ± a .RENAME.

where a copy of the signed matrix a is generated and named matrix c.

USER-Coded Subroutine statements have the general form:

c_1, (etc.) = $\pm a_1$, (etc.) .USERXX. $\pm b_1$, (etc.)

where computations are performed on the signed matrices $\underline{a}_1$, (etc.) and the signed matrices $\underline{b}_1$, (etc.) by the subroutine corresponding to the operation .USERXX. and the results are named matrices $\underline{c}_1$, (etc.), where $01 \leq xx \leq 09$.

If no output matrices are formed by the subroutine, indication is provided in the statement by an (*) to the left of the equal sign.

(5) Matrix Data

Card input matrix data are specified on the Standard Form shown on the following page.

A matrix header card having an H in card column 1, and containing the matrix name and its row and column dimensions is required for each matrix. The last card after all $MATRIX data must contain an E in card column 1 with the rest of the card blank.

Each matrix may contain up to 6000 randomly ordered elements. Machine sortability requires that the sequence number (first three digits) for each matrix is unique and identical in both header and element cards.

MAGIC
MATRIX/INPUT DATA FORMAT

	J MAX	MATRIX NAME	PROG. NO.	SEQ. NO.
	6 7 8 9	67 68 69 70 71 72	73 74 75 76	77 78 79 80

I	J	VALUE	EXP.	I	J	VALUE	EXP.	I	J	VALUE	EXP.	MATRIX NAME	PROG. NO.	SEQ. NO.
1 2 3 4 5	6 7 8 9	11 12 13 14 15 16 17 18 19	20 21 22	24 25 26 27	28 29 30 31	33 34 35 36 37 38 39 40 41	42 43 44	46 47 48 49	50 51 52 53	55 56 57 58 59 60 61 62 63	64 65 66	67 68 69 70 71 72	73 74 75 76	77 78 79 80

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d. USER04

The fourth user coded module of the program is the structural generator for the MAGIC System.

Since the .USER04. instruction plays a very important role in MAGIC II, a detailed analysis follows to aid the user in understanding the flexibility it provides to the total System.

(1) Input and Output Matrix Position Functions

The Structural Generative System may have as many as fifteen actual output matrices and require as many as four actual input matrices. The basic form of the .USER04. instruction may be represented as follows:

```
OMP1, OMP2, OMP3, OMP4, OMP5, OMP6, OMP7, OMP8,
OMP9, OMP10, OMP11, OMP12, OMP13, OMP14, OMP15 =
IMP1, IMP2, IMP3, IMP4 .USER04. ;
```

where OMP is read as output matrix position and IMP as input matrix position. All matrix positions, whether input or output, must be present. They may contain matrix names or be blank, but there must be nineteen matrix positions represented by the appropriate number of commas. Blank matrix positions are discussed in the next section. The output matrix positions, if nonblank, will contain the following matrices upon exit from the Structural Generative System:

OMP1	-	copy of input structure data deck
OMP2	-	revised material library
OMP3	-	interpreted input (structure input data as stored after being read and interpreted)
OMP4	-	external system grid point loads and load scalar matrix
OMP5	-	transformation matrix for application of boundary conditions
OMP6	-	transformation matrix for assembly of element matrices
OMP7	-	element stiffness matrices stored as one matrix
OMP8	-	element generated load matrices stored as one matrix
OMP9	-	element stress matrices stored as one matrix

OMP10	-	element thermal stress matrices stored as one matrix
OMP11	-	element incremental stiffness matrices stored as one matrix
OMP12	-	element mass matrices stored as one matrix
OMP13	-	structural system constants stored as one matrix
OMP14	-	element matrices in compressed format stored as one matrix
OMP15	-	prescribed displacement matrix

The input matrix positions, if nonblank must contain the following matrices:

IMP1	-	structure data deck (this would be a previously generated matrix saved in OMP1)
IMP2	-	interpreted input (this would be a previously generated matrix saved in OMP3 used for restart)
IMP3	-	existing material library (this would be a previously generated matrix saved in OMP2)
IMP4	-	displacement or stress matrix to be used for stability analyses (the stress matrix must have been generated by the structural abstraction instruction .STRESS.)

It should be noted that the following matrix positions are called matrices only in the sense that all input and output entities are considered matrices by FORMAT II - OMP1, IMP2, OMP3, OMP14, IMP1, IMP2 and IMP3.

It is important to note that OMP14 is mutually exclusive with OMP6, OMP7, OMP8, OMP9, OMP10, OMP11, and OMP12. In order to retain compatability with the MAGIC I system and eliminate redundant execution time, the following rules must be observed.

(a) If OMP14 is suppressed then OMP6, OMP7, OMP8, OMP9, OMP10, OMP11, and OMP12 will be generated according to their definition listed previously. If this is the case then it is assumed the user is using MAGIC I abstraction instructions to solve his problem.

(b) If OMP14 is not suppressed then OMP7, OMP8, OMP9, OMP10, OMP11 and OMP12 will serve only as indicators to the .USER04. instruction for generation or non-generation of their respective

element matrices. Since no matrices will be generated in OMP6 through OMP12 (if OMP14 is not suppressed) they should never be referenced in subsequent abstraction instructions.

(2) Suppression Option

Incorporated into the Structural Generative System is an option to suppress the generation and output of any of the output matrices and also to indicate the absence of any of the input matrices. This option is indicated to the Structural Generative System by the absence of a matrix name in the desired position in the .USERO4. instruction. A matrix name is considered to be absent if the matrix position contains all blanks or the character length of the name is zero. For example, an instruction of the form: ,, INTINP, LOADS, TR, TA, KEL, FEL, SEL, SZALEL,,,,, = ,,MATLB1, .USERO4.; would cause suppression of the copy of the data deck, the revised material library, the element incremental stiffness matrices, the element mass matrices, the structural system constant matrix, the compressed element matrix and the prescribed displacement matrix. The instruction also indicates that there is no input data deck on tape, (directing the Structural Generative System to read data from cards), no interpreted data on tape and no input data deck on tape, (directing the Structural Generative System to read data from cards), no interpreted data on tape and no input displacements or stresses. It should be noted that certain sections of the data deck are necessary for the generation of each of the output matrices and that error checking is done to determine if the required sections are present. Accordingly, error checking is invoked for the input matrix positions to determine if ambiguous or conflicting input indications have been made.

e. Use of FORMAT II Data Sets

(1) Master Input and Master Output Use for Material Library

References to the Material Library are indicated by output matrix position two and input matrix position three in the .USERO4. abstraction instruction. Retention of a newly generated or revised Material Library is governed solely by use of the SAVE abstraction instruction at the discretion of the User. If retention is desired, the matrix name and output matrix position two must appear in a SAVE abstraction instruction, in which case it will be placed on a Master Output tape. If a non-blank matrix name appears in input matrix position three, the Master Input Tape will be searched for that name.

Usage and generation of the Material Library is controlled by the three legal combinations of suppression of output matrix position two and input matrix position three. If the matrix name in output matrix position two is non-blank, but input matrix position three is suppressed, a new Material Library will be generated and used. If both involved matrix positions are non-blank, the old Material Library will be located on the Master Input tape, will be revised, stored as the matrix named in the specified output position, and then this revised Material Library will be used. If output matrix position two is suppressed and input matrix position three is non-blank, then the named input Material Library will be used: Suppression of both involved matrix positions results in an error condition.

Since the Material Library is stored under a matrix name on Master Output tapes, and also, therefore Master Input tapes, any other matrices may also be saved on the same tape, including other Material Libraries.

(2) Output Matrices

a. Output Matrix Position one (OMP1)

Contents	- Copy of card input data deck
Number of rows	- Set to eighty (80)
Number of columns	- Number of cards in data deck
Column records	- One data card per column record, one card column per row

b. Output Matrix Position Two (OMP2)

Contents	- Material library
Number of columns	- 306 (maximum number of words possible for one material entry)

Number of columns	- Number of material tables in library plus one
Column records	- One material table per column record.

c. Output Matrix Position Three (OMP3)

Contents	- Interpreted input
Number of rows	- Set to number of words in maximum record created
Number of columns	- Number of elements plus four
Column records	- One element input block per record.

d. Output Matrix Position Four (OMP4)

Contents	- External system grid point loads
Number of rows	- Number of degrees of freedom in total system plus 1
Number of columns	- Number of load conditions
Column records	- The first word is the external load scalar followed by one load condition per column record (use .DEJOIN. to obtain the load scalar).

e. Output Matrix Position Five (OMP5)

Contents	- Transformation matrix for application of boundary conditions
Number of rows	- Number of degrees of freedom in total system
Number of columns	- Number of degrees of freedom in total system
Column records	- (1) for desired degrees of freedom - contain a one in the assigned reduced degree of freedom row (2) for undesired degrees of freedom - column record is omitted (null column)

f. Output Matrix Position Six (OMP6)

Contents	- Transformation matrix for assembly of element matrices
Number of rows	- Number of degrees of freedom in total system
Number of columns	- Summation of element degrees of freedom
Column records	- Contain a one in the assigned degree of freedom row for that summed element degree of freedom

g. Output Matrix Position Seven (OMP7)

Contents	- Element stiffness matrices
Number of rows	- Summation of element degrees of freedom
Number of columns	- Summation of element degrees of freedom
Column records	- Each record contains a column of an element stiffness matrix

h. Output Matrix Position Eight (OMP8)

Contents	- Element applied load matrices
Number of rows	- Summation of element degrees of freedom
Number of columns	- One
Column record	- Contains all element applied load matrices

i. Output Matrix Position Nine (OMP9)

Contents	- Element stress matrices
Number of rows	- Summation of element stress point and component orders
Number of columns	- Summation of element degrees of freedom
Column records	- Each record contains a column of an element stress matrix

j. Output Matrix Position Ten (OMP10)

Contents	- Element thermal stress matrices
Number of rows	- Summation of element stress point and component orders
Number of columns	- One
Column record	- Contains all element thermal stress matrices

k. Output Matrix Position Eleven (OMP11)

Contents	- Element incremental stiffness matrix
Number of rows	- Summation of element degrees of freedom
Number of columns	- Summation of element degrees of freedom
Column records	- Each record contains a column of an element incremental stiffness matrix

l. Output Matrix Position Twelve (OMP12)

Contents	- Element mass matrices
Number of rows	- Summation of element degrees of freedom
Number of columns	- Summation of element degrees of freedom
Column records	- Each record contains a column of an element mass matrix

m. Output Matrix Position Thirteen (OMP13)

Contents	- System constants
Number of rows	- Twenty-seven
Number of columns	- One
Column record	- Nineteen structural system constants (for use outside of the .USER04. module)

The following is a description of the variables in this matrix:

Word 1 -	Number of directions allowed
Word 2 -	Number of types of movement allowed
Word 3 -	Number of reference points (highest reference node in element connections)
Word 4 -	Order of the reduced system (number of 1's plus 2's)
Word 5 -	Number of bounded degrees of freedom (number of 0's)
Word 6 -	Number of unknown degrees of freedom (number of 1's)
Word 7 -	Number of known degrees of freedom (number of 2's)
Word 8 -	Number of 0's plus 1's
Word 9 -	Element type code, equal to zero if word 1 = 3, equal to one otherwise
Word 10 -	Order of the total system
Word 11 -	Number of elements
Word 12 -	Number of load conditions
Word 13 -	Word 20 - Reserved for future expansion
Word 21 -	Number of eigenvalues requested
Word 22 -	Eigenvalue/vector convergence criteria
Word 23 -	Maximum number of iterations
Word 24 -	Control for iteration debug print
Word 25 -	First normalizing element for print
Word 26 -	Second normalizing element for print
Word 27 -	Control for guess vector iteration start

n. Output Matrix Position Fourteen (OMP14)

Contents	- Element matrices in compressed form
Number of rows	- Varies depending on problem
Number of columns	- One column for each element
Column records	- Each record contains all element matrices generated by .USER04. instruction in compressed form (to be used by structural modules outside of .USER04.)

o. Output Matrix Position Fifteen (OMP15)

Contents	- Prescribed displacements
Number of rows	- Number of degrees of freedom in system
Number of columns	- Number of load conditions
Column records	- One prescribed displacement condition per column record

f. Structural Abstraction Instructions To Be Used In Conjunction With The .USER04. Instruction

In designing the MAGIC II System for Structural Analysis, provision was made for accommodating new abstraction instructions peculiar to the .USER04.module. In keeping with the philosophy of generating a highly flexible USER oriented system, specialized instructions were designed for items such as element stress and force determination, element assembly and print controls. These additional USER options provide output capabilities of the MAGIC II System, consistent with input requirements.

The following abstraction instructions, .STRESS.,.FORCE.,.ASSEM. .EPRINT.,and .GPRINT.are to be used in conjunction with the .USER04. abstraction instruction. OMP will be used to represent an output matrix position name and IMP will be used to represent the input matrix position name when referring to the .USER04. instruction.

(1) To compute the net element stress matrix and generate optional engineering print of apparent element stresses, element applied stresses and net element stresses use the .STRESS. abstraction instruction.

C = A, B .STRESS. (d,e)

Where matrix A is OMP14 of the ,.USER04. instruction and Matrix B is a matrix containing the unredued displacement column for each load condition. The output matrix C will contain the net element stresses for each load condition. The following definitions apply:

d = 0, for no print
= 1, for apparent element stress print
= 2, for element applied stress print
= 3, for net element stress print
= 4, for apparent, applied, and net element stress print

e - an unsigned floating point number, with or without exponent, boundary matrix element values that are trivial and to be printed as zero. That is, the matrix element $c_{ij} = 0.0\ |C_{ij}| \leq e$.

If e is suppressed, then the value of e is defaulted to 0.0.

(2) To compute the net element force matrix and generate optional engineering print of apparent element forces, element applied forces and net element forces use the .FORCE. abstraction instruction.

C = A, B .FORCE. (d,e)

Where matrix A is OMP14 of the .USER04. instruction and matrix B is a matrix containing the unreduced displacement column for each load condition. The output matrix C will contain the net element forces for each load condition. The following definitions apply:

d = 0, for no print
= 1, for apparent element force print
= 2, for element applied force print
= 3, for net element force print
= 4, for apparent, applied, and net element stress pring

e an unsigned floating point number, with or without exponent, bounding matrix element values that are trivial and to be printed as zero. That is, the matrix element $c_{ij} = 0.0$ if $|C_{ij}| \leq e$. If e is suppressed, then the value of e is defaulted to 0.0.

(3) To generate engineering printout of the net element stresses or net element forces use the .EPRINT. abstraction instruction.

.EPRINT. (a, b, c) D

where matrix C is OMP14 from the .USER04. instruction and matrix D is either a net element stress matrix generated by a previous .STRESS. abstraction instruction or matrix D is a net element force matrix generated by a previous .FORCE. abstraction instruction. The following definitions apply.

a. - element matrix print code
a = 1, for net element stress print
a = 2, for net element force part

b. - an unsigned floating point number, with or without exponent, bounding matrix element values that are trivial and to be printed as zero. That is, the matrix element $d_{ij} = 0.0$ if $|d_{ij}| \leq b$.

If b is suppressed, then the value of b is defaulted to be 0.0.

(4) To assemble the element stiffness matrices, element mass matrices, element incremental matrices and element thermal load matrices as output by the .USER04. instruction use the .ASSEM. abstraction instruction.

C = A .ASSEM. B, (d)

where matrix A is OMP14 and matrix B is OMP13 of the .USER04. instruction, respectively. The output matrix C will be the assembled stiffness, mass, incremental or thermal load matrix depending on the value of d. The following definition applies:

d = 10, to assemble element stiffness matrix
= 20, to assemble element mass matrices
= 30, to assemble element incremental matrice
= 40, to assemble element applied load matrices

where for d = 10, 20, and 30 and [C] will have an order (NSYS x NSYS) and for d = 40, (NSYS x 1), where NSYS is the total number of system degree degrees of freedom for the structure being analyzed. If we let o's represent retained (or bounded) degrees of freedom, 1's represent unknown degrees of freedom, and 2's represent known degrees of freedoms then the matrix C will be ordered as follows:

$$C = \begin{bmatrix} C_{00} & C_{01} & C_{02} \\ C_{10} & C_{11} & C_{12} \\ C_{20} & C_{21} & C_{22} \end{bmatrix} \quad \text{or} \quad C = \begin{bmatrix} C_0 \\ C_1 \\ C_2 \end{bmatrix}$$

(5) To generate engineering printout of reactions, displacements, eigenvalues and eigenvectors, and user matrices use the .GPRINT. abstraction instruction.

.GPRINT. (a,b,c,C1.C2.C3.C4.C5.C6.C7.C8.C9.C10.C11.C12,D,E)F,G

where the arguments are defined as follows:

a. - print code to select type of print desired
a = 1, for reaction matrix print
a = 2, for displacement matrix print
a = 3, for eigenvalue and eigenvector matrix print
a = 4, for user matrix print

b. - an unsigned floating point number, with or without exponent, bounding matrix element values that are trivial and to be printed as zero. That is, the matrix element $f_{ij} = 0.0$ if $|f_{ij}| \leq b$. If b is suppressed, then the value of b is defaulted to be 0.0.

c. - a one to six character alphanumeric name which is printed as a label on the rows of the printed matrix F. If c is suppressed, then the default label is ROW.

C1 - C12 - Each C_i is a one to six character alphanumeric name which is printed as a label on the columns of the printed matrix F. It is possible to suppress any or all of the C_i. For each suppressed C_i a blank column label will be written over the corresponding column. If a C_i is suppressed then a dot (.) must be present to indicate its absence. If all column labels are suppressed, then no dots must be present and data between the last suppressed label and the comma need not be present.

D. This matrix must be OMP13 of the .USER04. instruction.

E. This matrix is optional. It may be suppressed if input matrix F is already in reduced form. If matrix F is unreduced, i.e., contains all system degrees of freedom then E must be a transformation matrix (OMP5) used to reduce matrix F for printing. If a = 3 then this matrix must be present.

F. The matrix to be printed, it can be the reaction, displacement, eigenvector or user matrix.

G. This matrix is input only when a = 3, and must contain the eigenvalues corresponding to the eigenvector. Otherwise, it must be omitted and no comma should be present to indicate its absence.

g. Abstraction Instructions For Structural Analyses

The previous sections have detailed the abstraction instructions available to the MAGIC II User.

Instructions of a general nature were discussed; i.e., .ADD., .MULT. etc. as well as instructions pertaining to the .USER04. module such as .STRESS. and .ASSEM.

This section will present the method of using these available instructions to perform structural analyses.

Instructions to perform the following types of analyses are presented.

1. Statics
2. Statics With Condensation
3. Statics With Prescribed Displacements
4. Stability
5. Dynamics (Modes and Frequencies)
6. Dynamics With Condensation

The analyses listed above may be performed in two different ways. In the first the User can elect to place the proper set of abstraction instructions in front of his structural input data deck for any given analyses. The second option, utilizes the Agendum level abstraction capability which has been incorporated into the MAGIC II System. Using this option, the abstraction instructions for the type of analyses desired are automatically generated by the System when the User specifies the corresponding option on the $Instruction Card. This Agendum level capability will be discussed in detail after the presentation and explanation of the abstraction instructions themselves.

(1) Statics Instruction Sequence (STATICS)

Figure II-c presents the suggested set of abstraction instructions for use in performing a linearly elastic displacement and stress analysis. It is to be noted that the User is not restricted to this particular set of instructions. The flexibility of the System allows the use of additional instructions to accommodate special needs and requirements of the User. As a supplement to the instructions listed in the Figure, Tables III, IV and V are provided. Table III lists definitions of terms used in each abstraction package, while Table IV provides engineering definition for each abstraction instruction which is executed by the System. In addition, Table V provides Matrix Definition for all matrices used in the STATICS Instruction Sequence.

```
$STATICS
C
C-----STATICS AGENDUM WITHOUT PRESCRIBED DISPLACEMENTS
C
C      *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *
C
C      STATICS INSTRUCTION SEQUENCE
C
C      *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *
C
C      GENERATE ELEMENT MATRICES
C
     ,ML 13,,XLD,TR,  ,KEL,FTEL,SEL,STEL,,,SC,EM,  =,,    ,.USER04.
C
C
C      FORM (1 X 1) UNIT AND (1 X 1) NULL MATRICES
C      DETERMINE PRINT FORMAT FOR TYPE OF ELEMENTS USED
C
     I1 = SC.IDENTC.
     I3 = I1.NULL.SC
     DIFF = I1 .SMULT. SC(9,1)
C
C      ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LOADS
C
     KELA = EM .ASSEM. SC,(10)
     FTELA = EM .ASSEM . SC,(40)
     LSCALE,LOADS = XLD .DEJOIN. (1,1)
C
C      REDUCE STIFFNESS MATRIX AND PRINT
C
     KC,KNO = KELA .DEJOIN.( SC(5,1),1)
     KCC,STIFF = KNO.DEJOIN.( SC(5,1),0)
     PRINT(FORCE,DISP,,) STIFF
C
C      FORM REDUCED TOTAL LOAD COLUMN
C
C      MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR
     FTELS = FTELA.MULT.LSCALE
C      TRANSFORM EXTERNAL LOADS TO 0-1-2 ASSEMBLED SYSTEM
     LOADO = TR.MULT.LOADS
C      FORM TOTAL LOAD COLUMNS
     TLOAD = FTELS.ADD.LOADO
     TL,TLOADR = TLOAD.DEJOIN.( SC(5,1),1)
C
C      SOLVE FOR DISPLACEMENTS
C
     XX = STIFF.SEQEL.TLOADR
     TRC,TR12 = TR.DEJOIN.(SC(5,1),1)
     X = TR12.TMULT.XX
     XO = TR.MULT.X
C
C      CALCULATE REACTIONS AND INVERSE CHECK
C
     REACTS = KELA.MULT.XO
     REACTP= REACTS.SUBT.TLOAD
     IF (DIFF.NULL.) GO TO 10
C
C      PRINT ELEMENT APPLIED LOADS, EXTERNAL LOADS, DISPLACEMENTS,
C        REACTIONS AND INVERSE CHECK IN ENGINEERING FORMAT
```

Figure II-c STATICS Agendum Without Prescribed Displacements

```
C
C        ELEMENTS HAVE 1 OR 2 DEGREES OF FREEDOM
C
      GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR )FTELA
      GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,    )LOADS
      GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,)X
      GPRINT(1,,,FX.FY.FZ.MX.MY.MZ,SC,TR )REACTP
      IF (I).NULL.) GO TO 6CO
C
C        ELFMENTS HAVE 3 DEGREES OF FREEDOM
C
 10   GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR )FTELA
      GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,    )LCADS
      GPRINT(2,,,U.0.W.0.THETAY.0.W*.0.W**,SC, )X
      GPRINT(1,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR )REACTP
C
C        GENERATE STRESSES AND FORCES
C
 600  STRESP=EM,XO .STRESS.(4,)
      FORCEP=EM,XO .FORCE.(4,)
```

Figure II-c STATICS Agendum (Concluded)

TABLE III

PRELIMINARY DEFINITIONS

Unordered System	-	The arrangement of the assembled system according to the boundary table and grid points. Points which are free, fixed or displaced are intermixed.
0's	-	Points which have a 0 boundary condition. No displacements are allowed at these points.
1's	-	Points which have a 1 boundary condition. Displacements are allowed at these points.
2's	-	Points which have prescribed displacements on them.
0-1 Ordered System	-	System where all 0's are placed first and all 1's after them. The ASSEM abstraction instruction generates matrices in this form. All processing by the abstraction sequences uses this form with the exception of the print routines. The system can be written as: $\begin{bmatrix} K_{00} & K_{01} \\ K_{10} & K_{11} \end{bmatrix} \begin{bmatrix} X_0 \\ X_1 \end{bmatrix} = \begin{bmatrix} P_0 \\ P_1 \end{bmatrix}$ Note that this system is the 0-1-2 ordered system with no 2's.
NSYS	-	The order of the assembled unreduced system, i.e., the number of 0's + 1's + 2's.
NMDB	-	The order of the reduced system (i.e., the number of 1's plus the number of 2's.

TABLE III
(CONCLUDED)

NMDBO	-	Number of 0's in the system.
NMDB1	-	Number of 1's in the system.
NMDB2	-	Number of 2's in the system.
NL	-	Number of load conditions in the problem.
0-1-2 Ordered System	-	System where all 0's are placed first, all 1's next, and finally all 2's are last. The ASSEM instruction generates matrices in this form. All processing by the abstraction instructions uses this form with the exception of the print routine. The system for the statics problem can be written as

$$\left[\begin{array}{c|c|c} K_{00} & K_{01} & K_{02} \\ \hline K_{10} & K_{11} & K_{12} \\ \hline K_{20} & K_{21} & K_{22} \end{array}\right] \begin{bmatrix} X_0 \\ X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} P_0 \\ P_1 \\ P_2 \end{bmatrix}$$

Note that this reduces to the 0-1 ordered system when NMDB2 = 0.

Reduced System	-	0-1-2 ordered system or 0-1 ordered system with 0's removed.
NL48	-	Product of the number of degrees of freedom for the element (maximum is 48) and the number of l ading conditions.
NELEM	-	Number of elements used in idealization
NVALUE	-	Number of eigenvalues and eigenvectors desired.

TABLE IV

STATICS INSTRUCTION SEQUENCE
(Step by Step Description)

Statement Number	Instruction and Explanation
1	,MLIB,,XLD,TR,,KEL,FTEL,SEL,STEL,,,SC,EM, =,,MATL,.USER04. Generates element matrices required for the statics problem. Note that names must be included for KEL, FTEL, SEL, STEL even though they are not used in the abstractions directly. The names must be present to insure that the matrices are generated by the module and placed in the EM array. MATL is an optional material library maintained by the user.
2	I1=SC.IDENTC. Forms a 1 x 1 identity matrix in I1. This corresponds to a scalar value of 1.0 which is used in multiplication later to form the print control matrix DIFF.
3	I3=I1.NULL.SC Forms a 1 x 1 null matrix which is used to generate unconditional 'GO TO' statements needed below.
4	DIFF=I1.SMULT.SC(9, 1) [DIFF]=[I1]*SC(9, 1) Forms the print control matrix which is used to generate the correct headings for engineering printout. A value of 0.0 for DIFF means that the elements and the system have 3 degrees of freedom per grid point. If DIFF is not zero, the system and elements have 1 or 2 degrees of freedom per grid point.

TABLE IV
(Continued)

Statement Number	Instruction and Explanation
5	KELA=EM.ASSEM.SC,(10) Forms the assembled stiffness matrix KELA in the 0-1 ordered system from the element stiffness matrices stored in EM as columns. SC contains system constants required by the .ASSEM. routine.
6	FTELA=EM.ASSEM.SC,(40) Forms the assembled element applied load column in the 0-1 ordered system from the element applied load columns stored in EM as columns.
7	LSCALE,LOADS=XLD.DEJOIN.(1,1) $\begin{bmatrix} \text{LSCALE} \\ \hline \text{LOADS} \end{bmatrix} = [\text{XLD}]$ The load scalars LSCALE and the external load columns LOADS are dejoined from the XLD matrix. The XLD matrix consists of the external columns with the corresponding load scalar as the first row.
8	KO,KNO=KELA.DEJOIN.(SC(5,1),1) $\begin{bmatrix} \text{KO} \\ \hline \text{KNO} \end{bmatrix} = [\text{KELA}]$ The NMDB rows of KELA which correspond to the 1's are formed in KNO.
9	KCO,STIFF=KNO.DEJOIN.(SC(5,1),0) $[\text{KCO} \mid \text{STIFF}] = [\text{KNO}]$ The (NMDB x NMDB) reduced stiffness matrix is formed in STIFF. Matrix STIFF is analogous to partition K_{11} in the definition of the 0-1 ordered system.
10	PRINT(FORCE,DISP,,) STIFF Prints the reduced stiffness matrix.

TABLE IV
(Continued)

Statement Number	Instruction and Explanation
11	FTELS=FTELA.MULT.LSCALE [FTELS] = [FTELA] [LSCALE] Forms NL element applied load columns by multiplying the element applied load column by the corresponding load scalar.
12	LOADO=TR.MULT.LOADS [LOADO] = [TR] [LOADS] Forms the transformed 0-1 assembled external load columns from the unordered LOADS.
13	TLOAD=FTELS.ADD.LOADO [TLOAD] = [FTELS] + [LOADO] Forms the total load column TLOAD = (scalar) * FTEL + LOADO in the 0-1 assembled system.
14	TL,TLOADR=TLOAD.DEJOIN.(SC(5,1),1) $\begin{bmatrix} \text{TL} \\ \text{TLOADR} \end{bmatrix}$ = [TLOAD] Forms the reduced total load column TLOADR which reflects only freepoints. TLOADR is analogous to partition P_2 in the definition of the 0-1 ordered system.
15	XX=STIFF.SEQEL.TLOADR [STIFF] [XX] = [TLOADR] Solves for the displacements in the reduced system XX by using Jordan elimination process to solve the system of simultaneous equations.

TABLE IV
(Continued)

Statement Number	Instruction and Explanation
16	TRO,TR12=TR.DEJOIN.(SC(5,1),1) $\begin{bmatrix} TRO \\ TR12 \end{bmatrix} = [TR]$ Forms matrix TR12 which when transposed will map the reduced system of XX into the full unordered system of displacements X.
17	X=TR12.TMULT.XX $X = [TR12]^T[XX]$ Forms unordered system of displacements used for printout in X.
18	XO=TR.MULT.X $[XO] = [TR]\ [X]$ Forms 0-1 ordered displacement columns in XO.
19	REACTS=KELA.MULT.XO $[REACTS] = [KELA]\ [XO]$ Forms product of assembled ordered stiffness matrix KELA and assembled ordered displacement columns XO.
20	REACTP=REACTS.SUBT.TLOAD $[REACTP] = [KELA]\ [XO] - [TLOAD]$ Forms reactions and inverse check in REACTP.
21	IF(DIFF.NULL.) GO TO Test print control for number of degrees of freedom per grid point.

TABLE IV
(Concluded)

Statement Number	Instruction and Explanation
22	GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR) FTELA
23	GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,) LOADS
24	GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,) X
25	GPRINT(1,,,FX.FY.FZ.MX.MY.MZ.SC,TR) REACTP
26	IF(I3.NULL.) GO TO 600
	Print out element applied loads, external loads, displacements, and reactions in engineering format for elements with 1 or 2 degrees of freedom. Control is then passed to statement numbered 600.
27	10 GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR) FTELA
28	GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,) LOADS
29	GPRINT(2,,,V.0.W.0.THETAY.0.W*.0.W**,SC,) X
30	GPRINT(1,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR)REACTP
	Print out element applied loads, external loads, displacements, and reactions in engineering format for elements with 3 degrees of freedom per grid point.
31	600 STRESP=EM,XO.STRESS.(4,)
	Calculates and prints net element stresses for each element and each load condition. The stress computations are based on displacements.
32	FORCEP=EM,XO.FORCE.(4,)
	Calculates and prints net element forces for each element and each load condition. The force computation is based on displacements.

TABLE V

MATRIX DEFINITIONS FOR STATICS

Matrix	Order	Definition
MLIB		Revised Material Library
XLD	(NSYS+1 X NL)	Unordered external load columns with load scalars as first row
TR	(NSYS X NSYS)	Transformation matrix from unordered assembled system into assembled 0-1-2 system
KEL		Element stiffness matrices generation control
FTEL		Element applied load columns generation control
SEL		Element stress matrices generation control
STEL		Thermal stress columns generation control
SC	(12 X 1)	System constants
EM		Contains all element matrices generated
		Stored as columns
KELA	(NSYS X NSYS)	Assembled 0-1 stiffness matrix
FTELA	(NSYS X 1)	Assembled 0-1 element applied load column
LSCALE	(1 X NL)	Load scalars for each load condition
LOADS	(NSYS X NL)	Unordered external load columns
I1	(1 X 1)	Scalar*Value +1
I3	(1 X 1)	Scalar*Value 0

TABLE V, Contd.

Matrix	Order	Definition
DIFF	(1 X 1)	SCALAR*Used to control print format
KO	(NMDBO X NSYS)	First NMDBO rows of KELA
KNO	(NMDB X NSYS)	Bottom NMDB rows of KELA
KCO	(NMDB X NMDBO)	First NMDBO columns of KNO
STIFF	(NMDB X NMDB)	Reduced stiffness matrix
FTELS	(NSYS X NL)	Assembled 0-1 element applied load column * Load Scalar, for each load condition
LOADO	(NSYS X NL)	Assembled 0-1 external load columns
TLOAD	(NSYS X NL)	Assembled 0-1 total load columns
TL	(NMDBO X NL)	First NMDBO rows of TLOAD
TLOADR	(NMDB X NL)	Reduced total load columns

TABLE V, (Concluded)

MATRIX DEFINITIONS FOR STATICS INSTRUCTION SEQUENCE

Matrix	Order	Definitions
XX	(NMDB X NL)	Reduced displacement columns
TRO	(NMDBO X NSYS)	First NMDBO rows of TR
TR12	(NMDB X NSYS)	Transpose of matrix which maps reduced system into unreduced/unordered system
X	(NSYS X NL)	Unordered assembled displacement columns
XO	(NSYS X NL)	Ordered 0-1 assembled displacement columns
REACTS	(NSYS X NL)	Product of assembled stiffness matrix and displacement columns (ordered)
REACTP	(NSYS X NL)	Reactions based on first load condition
STRESP	(NL48 X NELEM)	Element stress matrices stored for each load condition as columns
FORCEP	(NL48 X NELEM)	Element force matrices stored for each load condition as columns
NSYS		Order of assembled system
NL		Number of loading conditions
NMDBO		Number of 0's in system, (.e., number of points bounded out)
NMDB		Number of 1's in system, (i.e., number of free points)
NL48		Product of the number of degrees of freedom for the element (maximum is 48) and the number of loading conditions
NELEM		Number of elements used in idealization

(2) Statics Instruction Sequence With Condensation (STATICSC)

Figure II-d presents the suggested set of abstraction instructions for use in performing a linearly elastic displacement and stress analysis with condensation. The condensation (reduction) technique is that of Guyan (Reference 7). With the use of this option, the User is provided the flexibility to perform a static analysis utilizing a rational condensation procedure. The only basic difference in abstraction instructions between using the statics with condensation option and the standard statics option is the additional instructions required to form the condensed stiffness matrix, i.e.,

$$\left[K \right]_R = \left[K_{11} - K_{12}^{T} K_{22}^{-1} K_{21} \right]$$

These differences can be clearly noted upon comparison of STATICS (Figure II-c) with STATICSC (Figure II-d).

```
$STATICSC
C
C-----STATICS AGENDUM, WITH CONDENSATION
C
C       * * * * * * * * * * * * * * * * * * * * * * *
C                                                    *
C       STATICS INSTRUCTION SEQUENCE
C
C       * * * * * * * * * * * * * * * * * * * * * * *

C
C       GENERATE ELEMENT MATRICES
C
     ,MLIB,,XLD,TR,  ,KEL,FTEL,SFL,STEL,,,SC,EM,  =,,    ,.USER04.
C
C       FORM (1 X 1) UNIT AND (1 X 1) NULL MATRICES
C       DETERMINE PRINT FORMAT FOR TYPE OF ELEMENTS USED
     I1 = SC.IDENTC.
     I3 = I1.NULL.SC
     DIFF = I1 .SMULT. SC(9,1)
C
C       ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LOADS
C
     KELA = EM .ASSEM. SC,(10)
     FTELA = EM .ASSEM .SC,(40)
C
C       REDUCE STIFFNESS MATRIX AND PRINT
C
     KC,KNO = KELA .DEJOIN.( SC(5,1),1)
     KCC,STIFF = KNO.DEJOIN.( SC(5,1),0)
     PRINT(FORCE,DISP,,) STIFF
C
C       FORM REDUCED TOTAL LOAD COLUMN
C
     LSCALE,LOADS = XLD .DEJOIN.(1,1)
C       MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR
     FTELS = FTELA.MULT.LSCALE
C-----CONDENSE ASSEMBLED STIFFNESS MATRIX
     TOP,BOT = STIFF .DEJOIN. (SC(6,1),1)
     K11,K12 = TOP .DEJOIN. (SC(6,1),0)
     K12T,K22 = BOT .DEJOIN. (SC(6,1),0)
C
C-----CONDENSE EXTERNAL LOAD COLUMNS
     P0,P12 = LOADS .DEJOIN. (SC(5,1),1)
     P1,P2  = P12 .DEJOIN. (SC(6,1),1)
C
C-----FORM (K11 - K12*K22(INVS)*K12T)
C
     K22I =  -K22 .INVERS.
     KR1  = K22I .MULT. K12T
     KR2  = K12 .MULT.KR1
     KR =  K11 .ADD. KR2
C-----SOLVE FOR DISPLACEMENTS D1
     D1 =  KR .SEQFL. P1
C-----SOLVE FOR DISPLACEMENTS D2
     D2 =  KR1 .MULT. D1
```

Figure II-d Statics Agendum With Condensation

```
C-----FORM TOTAL DISPLACEMET VECTOR
      D1T = D1 .TRANSP.
      D2T = D2 .TRANSP.
      D12 = D1T .ADJOIN. D2T
      XX  = D12 .TRANSP.
C-----EXPAND DISPLACEMENTS TO TOTAL SYSTEM DEGREES OF
C-----FREEDOM AND REARRANGE TO 0-1-2 SYSTEM
      TR0,TR12 = TR.DEJOIN.(SC(5,1),1)
      X = TR12.TMULT.XX
      X0 = TR.MULT.X
C
C        CALCULATE REACTIONS AND INVERSE CHECK
C

      REACTS = KELA.MULT.X0
      REACTP= REACTS.SUBT.TLOAD
      IF (DIFF.NULL.) GO TO 10
C
C        PRINT ELEMENT APPLIED LOADS, EXTERNAL LOADS, DISPLACEMENTS,
C          REACTIONS AND INVERSE CHECK IN ENGINEERING FORMAT
C
C        ELEMENTS HAVE 1 OR 2 DEGREES OF FREEDOM
C
      GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR )FTELA
      GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,    )LOADS
      GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,)X
      GPRINT(1,,,FX.FY.FZ.MX.MY.MZ,SC,TR )REACTP
      IF (I3.NULL.) GO TO 600
C
C        ELEMENTS HAVE 3 DEGREES OF FREEDOM
C
 10   GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR )FTELA
      GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,    )LOADS
      GPRINT(2,,,U.0.W.0.THETAY.0.W*.0.W**,SC, )X
      GPRINT(1,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR )REACTP
C
C        GENERATE STRESSES  AND FORCES
C
 600  STRESP = EM,X0 .STRESS. (4,)
      FORCEP = EM,X0 .FORCE. (4,)
```

Figure II-d Statics Agendum With Condensation (Concluded)

(3) Statics Instruction Sequence with Prescribed Displacements (STATICS2)

Figure II-e presents the suggested set of abstraction instructions for use in performing a linearly elastic displacement and stress analysis with prescribed displacements. With the use of this option, applied loading may be prescribed in terms of non-zero displacement values. The number of prescribed displaced grid points is the number of grid points that are assigned known values of displacement other than zero. A specialized pre-printed input data form is provided for input of prescribed displacements. This form will be discussed in detail in the Structural Input Data Section.

Tables VI and VII are provided as supplements to Figure II-e. Table VI provides engineering definition for each abstraction instruction listed in Figure II-e; while Table VII provides matrix definition for all matrices used in the STATICS2 Abstraction Instruction Sequence.

```
$STATICS2
C
C-----STATICS AGENDUM WITH PRESCRIBED DISPLACEMENTS
C
C        STATICS INSTRUCTION SEQUENCE
C
C        GENERATE ELEMENT MATRICES
      .MLIB,.XLD,TP,  ,KEL,FTEL,SEL,STEL,,,SC,EM,PD=,,     ,.USER04.
C
C        FORM (1 X 1) UNIT AND (1 X 1) NULL MATRICES
C        DETERMINE PRINT FORMAT FOR TYPE OF ELEMENTS USED
C
      I1 = SC.IDENTC.
      I3 = I1.NULL.SC
      DIFF = I1 .SMULT. SC(9,1)
C
C        ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LOADS
C
      KELA = EM .ASSEM. SC,(10)
      FTELA = EM .ASSEM .SC,(40)
      LSCALE,LOADS = XLD .DEJOIN.(1,1)
C
C        REDUCE STIFFNESS MATRIX AND PRINT
C
      KC,KNO = KELA .DEJOIN.( SC(5,1),1)
      KCC,STIFF = KNO.DEJOIN.( SC(5,1),0)
      PRINT(FORCE,DISP,,) STIFF
C
C        MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR
      FTELS = FTELA.MULT.LSCALE
C        TRANSFORM EXTERNAL LOADS TO 0-1-2 ASSEMBLED SYSTEM
      LOADO  = TR.MULT.LOADS
C        FORM TOTAL LOAD COLUMNS
      TLOAD = FTELS.ADD.LOADO
      TL,TLOADR = TLOAD.DEJOIN.(SC(5,1),1)
C
C        SOLVE FOR DISPLACEMENTS
C        PRESCRIBED DISPLACEMENTS ARE PRESENT
C
```

Figure II-e Statics Agendum With Prescribed Displacements

```
C
      K1,K2 = STIFF.DEJOIN.(SC(6,1),1)
      K11,K12 = K1.DEJOIN.(SC(6,1),0)
      PDO = TR.MULT.PO
      PR,D2        = PDO   .DEJOIN.( SC(6,1),1)
      K3 = K12.MULT.D2
      P1,P2 = TLOADR.DEJOIN.(SC(6,1),1)
      K4 = P1.SUBT.K3
      X1 = K11.SEQEL.K4
      X1T = X1.TRANSP.
      X2T = D2.TRANSP.
      X12T = X1T.ADJOIN.X2T
      XCT = X1T.NULL.KCC
      XT = XCT.ADJOIN.X12T
      XO = XT.TRANSP.
      X = TR.TMULT.XO
C          CALCULATE AND PRINT REACTIONS
C
      REACTT = KELA.MULT.XO
      REACT = REACTT.SUBT.TLOAD
C
C          ELEMENTS HAVE 1 OR 2 DEGREES OF FREEDOM
C
C          PRINT ELEMENT APPLIED LOADS AND EXTERNAL LOADS
C          PRINT ASSEMBLED DISPLACEMENT COLUMN
C
      IF (DIFF.NULL.) GO TO 10
      GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR )FTELA
      GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,    )LOADS
      GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,)X
      GPRINT(1,,,FX.FY.FZ.MX.MY.MZ,SC,TR )REACT
      IF (I2.NULL.) GO TO 60
C
C          ELEMENTS HAVE 3 DEGREES OF FREEDOM
C
   10 GPRINT(4,,,FR.O.FZ.O.MBETA.O.F1.O.F3,SC,TR )FTELA
      GPRINT(4,,,FR.O.FZ.O.MBETA.O.F1.O.F3,SC,    )LOADS
      GPRINT(2,,,U.O.W.O.THETAY.O.W*.O.W**,SC,)X
      GPRINT(1,,,FR.O.FZ.O.MBETA.O.F1.O.F3,SC,TR )REACT
C
C          GENERATE STRESSES  AND FORCES
C
   60 STRESS = EM,XO .STRESS. (4,)
      FORCE = EM,XO .FORCE. (4,)
```


Figure II-e Statics Agendum With Prescribed Displacements (Continued)

TABLE VI

STATICS WITH PRESCRIBED DISPLACEMENTS INSTRUCTION SEQUENCE
(Step by Step Description)

Statement Number	Instruction and Explanation
1	,MLIB,,XLD,TR,,KEL,FTEL,SEL,STEL,,,SC, EM,PD=,,MATL,.USER04. Generate the element matrices needed for the statics problem with prescribed displacements. The names KEL, FTEL, SEL, STEL must be present to cause these matrices to be generated in EM. MATL is an optional material library maintained by the user.
2	I1=FTEL.IDENTC. [I1] = {1.0} Forms a (1 x 1) identity matrix in I1. The value of 1.0 will be used to form the print control matrix DIFF.
3	I3=I1.NULL.FTEL [I3] = {0.0} Forms a (1 x 1) null matrix in I3 which is used to generate an unconditional GO TO when used in an 'IF' instruction.
4	DIFF=I1.SMULT.SC(9, 1) DIFF = {1.0} * {SC(9,1)} Forms the print control matrix DIFF which is used to generate the correct headings for engineering printout. A value of 0.0 for DIFF means that the elements and the system have 3 degrees of freedom per grid point. If DIFF is non-zero, the elements and system have 1 or 2 degrees of freedom per grid point.

TABIE VI (Continued)

Statement Number	Instruction and Explanation
5	KELA=EM.ASSEM.SC,(10) Forms the 0-1-2 ordered assembled stiffness matrix KELA from the element stiffness matrices stored as columns in EM. SC contains system constants required by the ASSEM. routine.
6	FTELA=EM.ASSEM.SC,(40) Forms the 0-1-2 ordered assembled element applied load columns from the element applied load columns stored in EM.
7	LSCALE,LOADS=XLD.DEJOIN.(1,1) $\begin{bmatrix} LSCALE \\ \hline LOADS \end{bmatrix} = [XLD]$ The load scalars LSCALE and the external load columns LOADS are dejoined from the XLD matrix. XLD consists of the NL external load columns with the corresponding load scalar as the first row.
8	KO,KNO=KELA.DEJOIN.(SC(5,1),1) $\begin{bmatrix} KO \\ \hline KNO \end{bmatrix} = [KELA]$ The NMDB rows of KELA which correspond to 1's and 2's are formed in KNO.
9	KCO,STIFF=KNO.DEJOIN.(SC(5,1),0) $[KCO \vdots STIFF] = [KNO]$ The (NMDB x NMDB) reduced stiffness matrix is formed in STIFF. This matrix corresponds to the $\begin{bmatrix} K_{11} & \vdots & K_{12} \\ \hline K_{21} & \vdots & K_{22} \end{bmatrix}$ partitions in the definition of the 0-1-2 ordered system.

TABLE VI (Continued)

Statement Number	Instruction and Explanation
10	PRINT(FORCE,DISP,,) STIFF Prints the reduced stiffness matrix.
11	FTELS=FTELA.MULT.LSCALE [FTELS] = [FTELA] [LSCALE] Forms NL element applied load columns FTELS by multiplying the element applied load columns FTELA by the corresponding load scalar LSCALE.
12	LOADO=TR.MULT.LOADS [LOADO] = [TR] [LOADS] Transforms the unordered total load columns LOADS into the 0-1-2 ordered assembled load columns LOADO.
13	TLOAD=FTELS.ADD.LOADO [TLOAD] = [FTELA] [LSCALE] + [LOADO] Forms the NL total load column in the 0-1-2 ordered assembled system by adding the external load columns and a scalar times the element applied load column.
14	TL,TLOADR=TLOAD.DEJOIN.(SC(8,1),1) $\begin{bmatrix} TL \\ \hline TLOADR \end{bmatrix} = [TLOAD]$ Forms the reduced total load column TLOADR which reflects 1's and 2's. P2 is analogous to the P2 partition in the definition of the 0-1-2 ordered system.
15	K1,K2=STIFF.DEJOIN.(SC(6,1),1) $\begin{bmatrix} K1 \\ \hline K2 \end{bmatrix} = [STIFF]$ Forms the NMDB1 rows of STIFF which corresponds to 1's in K1. K1 corresponds to partitions $[K_{11} \vert K_{12}]$ in the definition of the 0-1-2 ordered system.

TABLE VI (Continued)

Statement Number	Instruction and Explanation
16	K11,K12=K1.DEJOIN.(SC(6,1),0) $\left[K11 \vdots K12\right] = \left[K1\right]$ Forms the submatrices K11 and K12 which correspond to the partitions with the same names in the definition of the 0-1-2 ordered system.
17	PDO=TR.MULT.PD $\left[PDO\right] = \left[TR\right] \left[PD\right]$ Transforms the unordered prescribed displacement columns PD into the 0-1-2 ordered assembled prescribed displacement columns PDO.
18	PR,D2=PDO.DEJOIN.(SC(8,1),1) $\begin{bmatrix} PR \\ \hdashline D2 \end{bmatrix} = \left[PDO\right]$ Forms the NMDB2 rows of PDO which correspond to the 2's in D2. D2 corresponds to partition X2 in the definition of the 0-1-2 ordered system.
19	K3=K12.MULT.D2 $\left[K3\right] = \left[K12\right] \left[D2\right]$ Forms the product of the K12 matrix and the D2 displacement columns in matrix K3.
20	P1,P2=TLOADR.DEJOIN.(SC(6,1),1) $\begin{bmatrix} P1 \\ P2 \end{bmatrix} = \left[TLOADR\right]$ Forms matrices P1 and P2 which correspond to the loads for 1's and 2's respectively.

TABLE VI (Continued)

Statement Number	Instruction and Explanation
21	K4=P1.SUBT.K3 $[K4] = [P1] - [K12]\ [D2]$ Forms the new reduced total load columns in K4. This represents the elimination of the prescribed displacements from the problem.
22	X1=K11.SEQEL.K4 $[K11]\ [X1] = [K4]$ Solves for the unknown displacements 1's using a Jordan elimination scheme to solve the reduced system of simultaneous equations.
23	X1T=X1.TRANSP. $[X1T] = [X1]^T$ Form the transpose of the displacement columns X1 in X1T.
24	X2T=D2.TRANSP. $[X2T] = [D2]^T$ Form the transpose of the prescribed displacement columns (2's) in X2T.
25	X12T=X1T.ADJOIN.X2T $[X12T] = [X1T]\ [X2T]$ Form the transpose of the displacement columns corresponding to 1's and 2's in X12T.
26	XOT=X1T.NULL.KCO Form a null matrix which represents the displacements for fixed points. (ie., no displacements are allowed for 0's).
27	XT=XOT.ADJOIN.X12T $[XT] = [XOT]\ [X12T]$ Form the transpose of the 0-1-2 ordered assembled displacement columns in XT.

TABLE VI (Continued)

Statement Number	Instruction and Explanation
28	XO=XT.TRANSP. $[XO] = [XT]^T$ Form the 0-1-2 ordered assembled displacement columns in XO.
29	X=TR.TMULT.XO $X = [TR]^T [XO]$ Form the unordered displacement columns in X which will be used for printout.
30	REACTT=KELA.MULT.XO $[REACTT] = [KELA]\ [XO]$ Forms the product of the 0-1-2 assembled stiffness matrix KELA and the 0-1-2 assembled ordered displacement columns XO.
31	REACT=REACTT.SUBT.TLOAD $[REACT] = [KELA]\ [XO] - [TLOAD]$ Forms the reactions and inverse check in REACT.
32	IF(DIFF.NULL.) GO TO 10 Test print control for number of degrees of freedom per grid point.
33 34 35 36 37	GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR) FTELA GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,) LOADS GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,) X GPRINT(1,,,FX.FY.FZ.MX.MY.MZ.SC,TR) REACT IF(I3.NULL.) GO TO 600 Print out element applied loads, external loads, displacements, and reactions in engineering format for elements with 1 or 2 degrees of freedom. Control is then passed to statement numbered 600.

TABLE VI (Concluded)

Statement Number	Instruction and Explanation
38	GPRINT(4,,,FR.O.FZ.O.MBETA.O.F1.O.F3,SC,TR)FTELA
39	GPRINT(4,,,FR.O.FZ.O.MBETA.O.F1.O.F3,SC,)LOADS
40	GPRINT(2,,,V.O.W.O.THETAY,O.W*.O.W**,SC,) X
41	GPRINT(1,,,FR.O.FZ.O.MBETA.O.F1.O.F3,SC,TR)REACT
	Print out element applied loads, external loads, displacements, and reactions in e engineering format for elements with 3 degrees of freedom per grid point.
42	600 STRESS=EM,XO.STRESS.(4,)
	Calculates and prints net element stresses for each element and each load condition. The stress computations are based on displacements.
43	FORCE=EM,XO.FORCE.(4,)
	Calculates and prints net element forces for each element and each load condition. The force computations is based on displacements.

TABLE VII

MATRIX DEFINITIONS FOR STATICS WITH PRESCRIBED DISPLACEMENTS

Matrix	Order	Definition
MLIB		Revised material library
XLD	(NSYS+1 X NL)	Unordered external load columns with load scalara as first row
TR	(NSYS X NSYS)	Transformation matrix from unordered assembled system into assembled 0-1-2 system
KEL		Element stiffness matrices generation control
FTEL		Element applied load columns generation control
SEL		Element stress matrices generation control
STEL		Thermal stress columns generation control
SC	(12 X 1)	System constants
EM		Contains all element matrices generated Stored as columns
PD	(NSYS X NL)	Unordered prescribed displacement columns
KELA	(NSYS X NSYS)	Assembled 0-1-2 stiffness matrix
FTELA	(NSYS X 1)	Assembled 0-1-2 element applied load column
LSCALE	(1 X NL)	Unordered external load columns

TABLE VII (Contd.)

Matrix	Order	Definition
LOADS	(NSYS X NL)	Unordered external load columns
I1	(1 X 1)	Scalar*Value+1
I3	(1 X 1)	Scalar*Value 0
DIFF	(1 X 1)	Scalar*Used to control print format
KO	(NMDBO X NSYS)	First NMDBO rows of KELA
KNO	(NMDB X NSYS)	Bottom NMDB rows of KELA
STIFF	(NMDB X NMDB)	Reduced 1-2 stiffness matrix
FTELS	(NSYS X NL)	Assembled 0-1-2 element applied load column*Load Scalar, for each load conditioned
LOADO	(NSYS X NL)	Assembled 0-1-2 external load columns
TLOAD	(NSYS X NL)	Assembled 0-1-2 total load columns
TL	(NMDBO X NL)	First NMDBO rows of TLOAD
TLOADO	(NMDB X NL)	Reduced 1-2 total load columns
K1	(NMDB1 X NMDB)	First NMDB1 rows of STIFF
K2	(NMDB2 X NMDB)	Last NMDB2 rows of STIFF
K11	(NMDB1 X NMDB1)	Upper left corner partition of STIFF
K12	(NMDB1 X NMDB2)	Upper right corner partition of STIFF
PDO	(NSYS X NL)	Assembled 0-1-2 prescribed displacement columns
PR	(NMDBO X NL)	First NMDBO rows of PDO
D2	(NMDB2 X NL)	Prescribed displacements corresponding to 2's

TABLE VII (Concluded)

Matrix	Order	Definition
P1	(NMDB1 X NL)	Load columns corresponding to 1's
P2	(NMDB2 X NL)	Load columns corresponding to 2's
K3	(NMDB1 X NL)	Product of matrices K12 and D2
K4	(NMDB1 X NL)	Load columns for reduced prescribed displacement system
X1	(NMDB1 X NL)	Displacements corresponding to 1's
X1T	(NL X NMDB1)	Matrix X1 transpose
X2T	(NL X NMDB2)	Matrix D2 transpose
X12T	(NL X NMDB)	Transposed 1-2 displacement columns
X0T	(NL X NMDB0)	Null matrix corresponding to 0's displacements
XT	(NL X NSYS)	Transposed 0-1-2 displacement columns
XO	(NSYS X NL)	0-1-2 displacement columns
X	(NSYS X NL)	Unordered displacement columns
STRESS	(NL48 X NELEM)	Element stress matrices stored for each load condition as columns
FORCE	(NL48 X NELEM)	Element force matrices stored for each load condition as columns
REACTT	(NSYS X NL)	Product of 0-1-2 assembled stiffness matrix and displacement columns
REACT	(NSYS X NL)	Reactions based on first load condition

(4) Stability Analysis Instruction Sequence (STABILITY)

Figure II-f presents the suggested set of abstraction instructions for use in performing elastic instability analyses. The abstraction instructions presented in Figure II-f are given engineering definition in Tables VIII and IX.

The structural stability analysis is a two-phase process, the first step of which is a linear elastic stress analysis for which the initial stress state is zero. The second phase of the analysis procedure, begins with the formation of element incremental stiffness matrices which are derived from the mid-plane stress resultants determined in the linear stress analysis. After assembly of element incremental stiffness matrices, a linear eigenvalue solution is obtained for the critical buckling load. Using this approach, the assumption is made that all mid-plane forces remain in a fixed ratio to one another at all levels of applied load, from the onset of loading to the achievement of instability. A detailed derivation of the algebraic expressions used for the Stability Analyses is given in Section III of the Engineer's Manual (Volume I).

It is to be noted that in the MAGIC II System, incremental stiffness matrices are provided for the following finite element representations:

a. Quadrilateral Plate (Identification No. 28)

b. Triangular Plate (Identification No. 27)

c. Incremental Frame (Identification No. 13)

The derivations of these elements are presented in detail in the Engineer's Manual, Volume I. In addition, the Element Input Section o. this manual provides additional description for the proper usage of these elements within the MAGIC II System.

```
$STABILITY
C
C-----STABILITY AGENDUM ANALYSIS
C
C         STABILITY ANALYSIS INSTRUCTION SEQUENCE
C
C         GENERATE ELEMENT MATRICES
C
      ,MLIB,INTP,XLD ,TR,   ,KEL,FTEL,SEL,STEL,,,SC,EM,=,,      ,,USER04.
C
C         FORM (1 X 1) UNIT AND (1 X 1) NULL MATRICES
C         DETERMINE PRINT FORMAT FOR TYPE OF ELEMENTS USED
C
      I1 = SC.IDENTC.
      I3 = I1.NULL.SC

      DIFF = I1 .SMULT. SC(9,1)
C
C         ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LOADS
C
      STIFF= EM .ASSEM. SC,(1)
      FTELA = EM .ASSEM .SC,(40)
      LSCALE,LOADS = XLD .DEJOIN.(1,1)
      PRINT(FORCE,DISP,,) STIFF
C
C         MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR
      FTELS = FTELA.MULT.LSCALE
C         TRANSFORM EXTERNAL LOADS TO 0-1-2 ASSEMBLED SYSTEM
      LOADO = TR.MULT.LOADS
C         FORM TOTAL LOAD COLUMNS
      TLOAD = FTELS.ADD.LOADO
C         FORM REDUCED TOTAL LOAD COLUMN
      TL,TLOADR = TLOAD.DEJOIN.( SC(5,1),1)
C
C         PRINT FLEXIBILITY  MATRIX
C
      FLEX = STIFF.INVERS.
      PRINT (DISP,FORCE,,) FLEX
C
C         SOLVE FOR DISPLACEMENTS
C
      XR= FLEX.MULT.TLOADR
      TRC,TR12 = TR.DEJOIN.(SC(5,1),1)
      X = TR12.TMULT.XR
      XO = TR.MULT.X
      IF (DIFF.NULL.) GO TO 10
C
```


Figure II-f   Stability Agendum

```
C         PRINT ELEMENT APPLIED LOADS AND EXTERNAL LOADS
C
C         ELEMENTS HAVE 1 OR 2 DEGREES OF FREEDOM
C
      GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR )FTELA
      GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,    )LOADS
      GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,   ) X
      IF (I3.NULL.) GO TO 60
C
C         ELEMENTS HAVE 3 DEGREES OF FREEDOM
C
 10   GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR )FTELA
      GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,    )LOADS
      GPRINT(2,,,U.0.W.0.THETAY.0.W*.0.W**,SC,   ) X
C
C         GENERATE STRESSES
C
 60   STRESS = FM,XO .STRESS. (4,)
C
C         GENERATE ELEMENT INCREMENTAL STIFFNESS MATRIX
C
      ,,,,,,,,,,NEL,,  ,EL,=,INTP,    ,STRESS.USER04.
C
C         ASSEMBLE AND REDUCE INCREMENTAL MATRIX
C
      INCR = EL .ASSEM. SC,(3)
      PRINT(,,,) INCR
C

C         CREATE INPUT EIGENVALUE MATRIX
C
      EIG = FLEX.MULT.INCR
      PRINT (,,,) EIG
C
C         CALCULATE AND PRINT E-VALUES,E-VECTORS,FRECUENCIES
C
      EVALUE,EVECTR,, = EIG, .EIGEN1. SC
      GPRINT(3,,,,SC,TR12) EVECTR,EVALUE
```

Figure II-f - Stability Agendum (continued)

TABLE VIII

STABILITY INSTRUCTION SEQUENCE
(Step by Step Description)

Statement Number	Instruction and Explanation
1	,MLIB,INTP,XLD,TR,,KEL,FTEL,SEL,STEL,,, SC,EM,=,,MATL,.USER04. Generates element matrices required for the statics problem. Note that names must be included for KEL, FTEL, SEL, STEL even though they are not used in the abstractions directly. The names must be present to insure that the matrices are generated by the module and placed in the EM array. MATL is an optional material library maintained by the user.
2	I1=FTEL.IDENTC. Forms a 1 x 1 identity matrix in I1. This corresponds to a scalar value of 1.0 which is used in multiplication later to form the print control matrix DIFF.
3	I3=I1.NULL.FTEL Forms a 1 x 1 null matrix which is used to generate unconditional 'GO TO' statements needed below.
4	DIFF=I1.SMULT.SC(9,1) [DIFF] = [I1] * SC(9,1) Forms the print control matrix which is used to generate the correct headings for engineering printout. A value of 0.0 for DIFF means that the elements and the system have 3 degrees of freedom per grid point. If DIFF is not zero, the system and elements have 1 or 2 degrees of freedom per grid point.

TABLE VIII (Continued)

Statement Number	Instruction and Explanation
5	STIFF=EM.ASSEM.SC,(1) Forms the assembled stiffness matrix STIFF in the (NMDBxNMDB) reduced system from the element stiffness matrices stored in EM as columns. SC contains system constants required by the.ASSEM.routine.
6	FTELA=EM.ASSEM.SC,(40) Forms the assembled element applied load column in the 0-1 ordered system from the element applied load columns stored in EM as columns.
7	LSCALE,LOADS=XLD.DEJOIN.(1,1) $\left[\frac{\text{LSCALE}}{\text{LOADS}}\right] = \left[\text{XLD}\right]$ The load scalars LSCALE and the external load columns LOADS are dejointed from the XLD matrix. The XLD matrix consists of the external columns with the corresponding load scalar as the first row.

TABLE VIII (Continued)

Statement Number	Instruction and Explanation
8	PRINT(FORCE,DISP,,) STIFF Prints the reduced stiffness matrix.
9	FTELS=FTELA.MULT.LSCALE [FTELS] = [FTELA] [LSCALE] Forms NL element applied load columns by multiplying the element applied load column by the load scalar.
10	LOADO=TR.MULT.LOADS [LOADO] = [TR] [LOADS] Forms the transformed C-1 assembled external load columns from the unordered LOADS.
11	TLOAD=FTELS.ADD.LOADS [TLOAD] = [FTELS] + [LOADS] Forms the total load column TLOAD = (scalar) * FTEL + LOADO in the 0-1 assembled system.
12	TL, TLOADR=TLOAD.DEJOIN.(SC(5,1),1) $\left[\begin{array}{c} TL \\ \hdashline TLOADR \end{array}\right] = [TLOAD]$ Forms the reduced total load column TLOADR which reflects only free points. TLOADR is analogous to partition P_2 in the definition of the 0-1 ordered system.

TABLE VIII (Continued)

Statement Number	Instruction and Explanation
13	FLEX=STIFF.INVERS. $[FLEX] = [STIFF]^{-1}$ Forms the inverse of the reduced stiffness matrix in KINV.
14	PRINT(DISP,FORCE,,) FLEX Print inverse of stiffness matrix (flexibility matrix).
15	XR=FLEX.MULT.TLOADR $[XR] = [STIFF]^{-1}[TLOADR]$ Form reduced displacement column in XR by forming the product of the flexibility matrix and the reduced total load columns.
16	TRO,TR12=TR.DEJOIN.(SC(5,1,1) $\begin{bmatrix} TRO \\ TR12 \end{bmatrix} = [TR]$ Forms matrix TR12 which when transposed will map the reduced system of displacements XR into the full unordered system of displacements X.
17	X=TR12.TMULT.XR $[X] = [TR12]^T[XR]$ Forms the unordered system of displacement used for print out in X.
18	XO=TR.MULT.X $[XO] = [TR]\ [X]$ Forms the 0-1 ordered system of displacements in XO.

TABLE VIII (Continued)

Statement Number	Instruction and Explanation
19	IF(DIFF.NULL.) GO TO 10 Test print control for number of degrees of freedom per grid point.
20 21 22 23	GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR) FTELA GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,) LOADS GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,) X IF(I3.NULL.) GO TO 60 Print out element applied loads, external loads, and displacements, in engineering format for elements with 1 or 2 degrees of freedom. Control is then passed to statement numbered 600.
24 25 26	GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,TR)FTELA GPRINT(4,,,FR.0.FZ.0.MBETA.0.F1.0.F3,SC,)LOADS GPRINT(2,,,V.0.W.0.THETAY.0.W*.0.W**,SC,)X Print out element applied loads, external loads, and displacements, in engineering format for elements with 3 degrees of freedom per grid point.
27	STRESS=EM,XO.STRESS.(4,) Calculates and prints net element stresses for each element and each load condition. The stress computations are based on displacements.
28	,,,,,,,,,,NEL,,,EL,*,INTP,,STRESS.USER04. Generates the element incremental stiffness matrices based on the interpreted input generated by the first USER04 instruction and the STRESS matrix.
29	INCR =EL.ASSEM.SC,(3) Assembles the (NMDBxNMDB) reduced incremental stiffness matrix INCR. The element incremental stiffness matrices are stored in EL.

TABLE VIII (Concluded)

Statement Number	Instruction and Explanation
30	PRINT(,,,) INCR Prints the reduced incremental stiffness matrix.
31	EIG=FLEX.MULT.INCR $[EIG] = [STIFF]^{-1} [INCR]$ Forms the product of the inverse of the reduced stiffness matrix and the reduced incremental stiffness matrix.
32	PRINT(,,,)EIG Prints the eigenvalue matrix.
33	EVALUE,EVECTR,,=EIG,.EIGEN1.SC $\left[[EIG] - [EVALUE]\ [I]\right] [EVECTR] = 0$ Solves for the requested eigenvalues and eigenvectors of the EIG matrix using the power method. The eigenvalues are stored in the column matrix EVALUE and the eigenvectors are stored as columns in the EVECTR matrix. The frequencies and mode shapes are printed out along with the eigenvalues and eigenvectors.
34	GPRINT(3,,,,SC,TR12)EVECTR,EVALUE Prints the eigenvalue column and the eigenvector matrix in engineering format.

TABLE IX

MATRIX DEFINITION FOR STABILITY

Matrix	Order	Definition
MLIB		Revised material library
INTP		Interpreted input deck
XLD	(NSYS+1 X NL)	Unordered external load columns with load scalars as first row
TR	(NSYS X NSYS)	Transformation matrix from unordered assembled system into assembled 0-1 system
KEL		Element stiffness matrices generation control
FTEL		Element applied load columns generation control
SEL		Element stress matrices generation control
STEL		Thermal stress columns generation control
SC	(12 X 1)	System constants
EM		Contains all element matrices generated
		Stored as columns
FTELA	(NSYS X 1)	Assembled 0-1 element applied load column
LSCALE	(1 X NL)	Load scalars for each load condition
LOADS	(NSYS X NL)	Unordered external load columns

TABLE IX, (Contd)

Matrix	Order	Definition
I1	(1 X 1)	Scalar*Value+1
I3	(1 X 1)	Scalar*Value 0
DIFF	(1 X 1)	Scalar*Used to control print format
STIFF	(NMDB X NMDB)	Reduced 1-2 stiffness matrix
FTELS	(NSYS X NL)	Assembled 0-1 element applied load column* load scalar, for each load condition
LOADO	(NSYS X NL)	Assembled 0-1 external load columns
TLOAD	(NSYS X NL)	Assembled 0-1 total load columns
TL	(NMDBO X NL)	First NMDBO rows of TLOAD
TLOADO	(NMDB X NL)	Reduced total load columns
FLEX	(NMDB X NMDB)	Inverse of reduced stiffness matrix
XR	(NMDB X NL)	Reduced displacement columns
TRO	(NMDBO X NSYS)	First NMDBO rows of TR
TR12	(NMDB X NSYS)	Transpose of matrix which maps reduced system into unreduced/unordered system
X	(NSYS X NL)	Unordered assembled displacement columns
XO	(NSYS X NL)	Ordered 0-1 assembled displacement columns
STRESS	(NL48 X NELEM)	Element stress matrices stored for each load condition as columns

TABLE IX , (Contd.)

Matrix	Order	Definition
NEL		Element incremental matrices generation control
EL		Element incremental matrices stored as columns
INCR	(NMDB X NMDB)	Reduced incremental stiffness matrix
EIG	(NMDB X NMDB)	Product of flexibility matrix and reduced incremental stiffness matrix
EVALUE	(NVALUE X 1)	Eigenvalues of EIG matrix stored as columns
EVECTOR	(NMDB X NVALUE)	Eigenvectors of EIG matrix stored as columns

(5) Dynamics Analysis Instruction Sequence (DYNAMICS)

Figure II-g presents the suggested set of abstraction instructions for use in performance of a vibration analysis. This particular set of instructions provides modes and frequencies for a structural system in which the rigid body modes have been suppressed (i.e. the assembled stiffness matrix has been rendered non-singular by the appropriate application of physical boundary conditions. As seen from Figure II-g the .EIGEN 1. abstraction instruction is used in this sequence. As pointed out previously this instruction is based on the "power method" of extracting eigenvalues and eigenvectors. The desired number of modes and frequencies are supplied as input by the User in the Structural Analysis Input Section. This information is contained on a specialized preprinted input data form entitled DYNAM. This form will be described in detail in the Structural Input Data Section.

Additional output data from this set of instructions include generalized mass and generalized stiffness values for each mode.

Tables X and XI are provided as a supplement to Figure II-g. These tables provide engineering and matrix definition for each abstraction instruction listed in Figure II-g.

It should be noted, and emphasized, that this set of example abstraction instructions which have been presented serve only to provide the User with a guide for usage of abstractions for a particular type of analyses. The User, at his option, can modify any set of abstractions to fit his particular need. As an example, the User may have a problem which requires "non-structural" masses to be added to the structural mass matrix which is assembled by the System.

If this is the case, the assembled mass matrix is modified by adding the non-structural mass matrix with an available .ADD. instruction and the analysis then proceeds in the usual manner. In general, the non-structural mass matrix would be supplied to the program as input data thru the $ matrix option which has been explained previously.

```
$DYNAMICS
C
C-----DYNAMICS AGENDUM ANALYSIS
C
C        DYNAMICS ANALYSIS INSTRUCTION SEQUENCE
C
C        GENERATE ELEMENT MATRICES
C
      ,MLI3,,,TR,,KEL,,,,,MEL,SC,EM, = ,,, .USER04.
C
C        ASSEMBLE STIFFNESS MATRIX AND MASS MATRIX
C
      STIFF= EM .ASSEM. SC,(1)
      MASS = EM .ASSEM. SC,(2)
C
C        PRINT STIFFNESS MATRIX AND MASS MATRIX
C
      PRINT(FORCE,DISP,,) STIFF
C
      PRINT(FORCE,ACCEL,,) MASS
C
C        GENERATE DYNAMICS MATRIX
C
      KINV = STIFF.INVERS.
      DYNAM = KINV.MULT.MASS
C
C        FIND E-VALUES, E-VECTORS, NORMAL MODES,
C        FREQUENCIES AND PRINT
C
      EVALUE,EVECT,, = DYNAM, .EIGEN1. SC
C
      TRC,TR12 = TR .DEJOIN. (SC(5,1),1)
      GPRINT(3,,,,SC,TR12) EVECT,EVALUE
C
C        GENERATE STIFFNESS AND GENERALIZED MASS
C        MATRICES AND PRINT
C
      KGEN1 = EVECT.TMULT.STIFF
      KGEN = KGEN1.MULT.EVECT
      MGEN1 = EVECT.TMULT.MASS
      MGEN = MGEN1.MULT.EVECT
      PRINT(,,,) MGEN,KGEN,KINV,DYNAM
```


Figure II-g Dynamics Agendum Analysis Sequence

TABLE X

DYNAMICS INSTRUCTION SEQUENCE

(Step by Step Description)

Statement Number	Instruction and Explanation
1	.MLIB,,,,,KEL,,,,,MEL,SC,EM,=,,MATL,.USERO4. Generates the element stiffness matrices KEL and element mass matrices MEL needed for the dynamics problem. Note that names must be present for KEL and MEL even though they are not used in the abstractions directly. The names must be present to insure that the matrices are generated and placed in the EM array. MATL is an optional material library maintained by the user.
2	STIFF=EM.ASSEM.SC,(1) Forms the assembled stiffness matrix STIFF from the element stiffness matrices stored in EM. SC contains system constants required by the .ASSEM. routine.
3	MASS=EM.ASSEM.SC,(2) Forms the (NMDBxNMDB) reduced mass matrix in MASS from the element mass matrices stored in EM. System information required by .ASSEM. is input in SC.
4	PRINT(FORCE,DISP,,) STIFF Prints the reduced stiffness matrix.
5	PRINT(DISP,FORCE,,) MASS Prints the reduced mass matrix.
6	KINV=STIFF.INVERS. $[KINV] = [STIFF]^{-1}$ The inverse of the reduced stiffness matrix is formed in KINV.
7	DYNAM=KINV.MULT.MASS $[DYNAM] = [STIFF]^{-1} [MASS]$ Forms the product of the inverse of the reduced stiffness matrix KINV and the reduced mass matrix MASS in the dynamics matrix DYNAM.

TABLE X (Continued)

Statement Number	Instruction and Explanation
8	EVALUE,EVECTR,,=DYNAM,.EIGEN1.SC solve $\left[[DYNAM] - [EVALUE][I]\right] [EVECTR] = [0]$ Computes the required eigenvalues and corresponding eigenvectors of the dynamics matrix using the power method. The eigenvalues are stored in the column matrix EVALUE and the corresponding eigenvectors are stored as columns in EVECTR. The frequencies and mode shapes are also printed out.
9	KGEN1=EVECT.TMULT.STIFF $[KGEN1] = [EVECT]^T [STIFF]$ Forms the product of the transpose of the eigenvector matrix and the reduced stiffness matrix.
10	KGEN=KGEN1.MULT.EVECT $[KGEN] = [EVECT]^T [STIFF]\ [EVECT]$ Forms the generalized stiffness matrix in KGEN by forming the product of KGEN1 and EVECT.
11	MGEN1=EVECT.TMULT.MASS $[MGEN1] = [EVECT]^T [MASS]$ Forms the product of the transpose of the eigenvalue matrix and the reduced mass matrix.
12	MGEN=MGEN1.MULT.EVECT $[MGEN] = [EVECT]^T [MASS]\ [EVECT]$ Forms the generalized mass matrix in MGEN by forming the product of MGEN1 and EVECT.

TABLE X (Concluded)

Statement Number	Instruction and Explanation
13	PRINT(,,,)MGEN,KGEN,KINV,DYNAM Print the generalized stiffness matrix, generalized mass matrix, inverse of the stiffness matrix and the dynamics matrix.
14	TRO,TR12 = TR.DEJOIN.(SC(5,1),1) $\begin{bmatrix} TRO \\ \hline TR12 \end{bmatrix} = \begin{bmatrix} TR \end{bmatrix}$ Forms the matrix TR12 which will be used by the .GPRINT. instruction.
15	.GPRINT.(3,,,,SC,TR12)EVECT,EVALUE Print the eigenvalue column and the eigenvector matrix in engineering format.

TABLE XI

MATRIX DEFINITIONS FOR DYNAMICS INSTRUCTION SEQUENCE

Matrix	Order	Definition
MLIB		Revised material library
KEL		Element stiffness matrices generation control
MEL		Element mass matrices generation control
SC	(12 X 1)	System constants used in .USER04. module
EM		Element stiffness matrices and element mass matrices stored as columns for each element
STIFF	(NMDB X NMDB)	Reduced stiffness matrix
MASS	(NMDB X NMDBO)	Reduced mass matrix
KINV	(NMDB X NMDB)	Inverse of stiffness matrix
DYNAM	(NMDB X NMDB)	Dynamics matrix
EVALUE	(NVALUE X 1)	Eigenvalues of dynamics matrix stored as columns
EVECT	(NMDB X NVALUE)	Eigenvectors of dynamics matrix stored as columns
KGEN1	(NVALUE X NMDB)	Product of E-value matrix and stiffness matrix
KGEN	(NVALUE X NVALUE)	Generalized stiffness matrix
MGEN1	(NVALUE X NMDB)	Product of E-value matrix and mass matrix
MGEN	(NVALUE X NVALUE)	Generalized mass matrix

(6) Dynamics Instruction Sequence With Condensation (DYNAMICSC)

Figure II-h presents the suggested set of abstraction instructions for use in the performance of a vibration analysis utilizing condensation. The condensation technique utilized is that of Guyan (Reference 7).

The use of this technique allows degrees of freedom considered to be superflous to be eliminated through a condensation transformation. This technique yields a eigenvalue problem which is much reduced in size.

Degrees of freedom that are to be eliminated in a particular analyses are designated by the number '2' in the Bondary Condition Section which will be discussed in detail in the next section.

Given below is a detailed algebraic statement of the condensation procedure which is performed using the Instructions of Figure II-h.

The equations of motion which govern dynamic response of structural systems can be written in matrix notation as follows:

$$\left[M_2\right] \left\{\ddot{\delta}_2\right\} + \left[K_2\right] \left\{\delta_2\right\} = \left\{F\right\} \qquad (A)$$

The corresponding strain and kinetic energy functionals for this equation can be written as follows:

$$\Phi_U = 1/2 \left\lfloor \delta_2 \right\rfloor \left[K_2\right] \left\{\delta_2\right\} \qquad (B)$$

for the strain energy and

$$\Phi_K = 1/2 \left\lfloor \dot{\delta}_2 \right\rfloor \left[M_2\right] \left\{\dot{\delta}_2\right\} \qquad (C)$$

The assumption made in applying this technique is that the complete set of gridpoint displacement degrees of freedom $\left\{\delta_2\right\}$ are not essential to the objective structural dynamics analyses. For example, the gridpoints in the finite element model may have been dictated by the natural breakdown of the structure into components, or the intended use of the model for stress analyses.

The complete set of substructure gridpoint displacement degrees of freedom is partitioned to reflect the division into essential $\{\delta_{2a}\}$ and superfluous $\{\delta_{2b}\}$ subsets. Partitioning of the displacement set implies a corresponding partitioning of the total potential energy as

$$\Phi_p = \frac{1}{2}\left\lfloor \lfloor \delta_{2a} \rfloor, \lfloor \delta_{2b} \rfloor \right\rfloor \left[\begin{array}{c|c} [K_{2aa}] & [K_{2ab}] \\ \hline [K_{2ab}]^T & [K_{2bb}] \end{array}\right] \left\{\begin{array}{c} \delta_{2a} \\ \hline \delta_{2b} \end{array}\right\} - \left\lfloor \lfloor \delta_{2a} \rfloor, \lfloor \delta_{2b} \rfloor \right\rfloor \left\{\begin{array}{c} \{P_{2a}\} \\ \hline \{P_{2b}\} \end{array}\right\}. \tag{1}$$

By definition, the $\{\delta_{2b}\}$ are superfluous to the objective structural dynamics analyses. This being the case, they are condensed from the model via the static principle of potential energy. This principle yields a matrix equation governing static behavior, i.e.,

$$\left[\begin{array}{c|c} [K_{2aa}] & [K_{2ab}] \\ \hline [K_{2ab}]^T & [K_{2bb}] \end{array}\right] \left\{\begin{array}{c} \{\delta_{2a}\} \\ \hline \{\delta_{2b}\} \end{array}\right\} = \left\{\begin{array}{c} \{P_{2a}\} \\ \hline \{P_{2b}\} \end{array}\right\} \tag{2}$$

Solution of this relation for the superflous degrees of freedom in terms of the essential degrees of freedom produces a condensing transformation relation of the form

$$\{\delta_2\} = \{\tau_3\} + [\Gamma_3]\{\delta_3\} \tag{3}$$

where

$$\{\delta_3\} = \{\delta_{2a}\} \tag{4}$$

and

$$\left[\Gamma_3\right] = \left[\begin{array}{c} [\,I\,] \\ \hline -\left[K_{2bb}\right]^{-1}\left[K_{2ab}\right] \end{array}\right] \tag{5}$$

$$\left\{\gamma_3\right\} = \left\{\begin{array}{c} \{0\} \\ \hline \left[K_{2bb}\right]^{-1}\left\{P_{2b}\right\} \end{array}\right\}. \tag{6}$$

Introducing the condensation transformation of Equation 3 into the energy functions of Equation 1 references these functions to essential degrees of freedom. For example, application to the strain energy Equation B yields

$$\Phi_U = \frac{1}{2}\left\lfloor \delta_3 \right\rfloor \left[K_3\right]\left\{\delta_3\right\} \tag{7}$$

where

$$\left[K_3\right] = \left[\Gamma_3\right]^T\left[K_2\right]\left[\Gamma_3\right]. \tag{8}$$

The other energy functions are similarly transformed as follows:

$$\Phi_K = 1/2 \left\lfloor \dot{\delta}_3 \right\rfloor \left[M_3\right] \left\{\dot{\delta}_3\right\} \tag{9}$$

where

$$\left[M_3\right] = \left[\Gamma_3\right]^T \left[M_2\right] \left[\Gamma_3\right] \tag{10}$$

The introduction of this condensation transformation to the set of stiffness and mass matrices can substantially reduce the order of the matrices involved in the determination of modes and frequencies.

```
$DYNAMICSC
C
C----- DYNAMICS AGENDUM, WITH CONDENSATION
C
C-----DYNAMICS AGENDUM ANALYSIS
C
C        DYNAMICS ANALYSIS INSTRUCTION SEQUENCE
C
C        GENERATE ELEMENT MATRICES
C
      ,MEMB,,,TR,,KEL,,,,,MEL,SC,EM, = ,,, .USER04.
C
C        ASSEMBLE STIFFNESS MATRIX AND MASS MATRIX
C
      STIFF = EM .ASSEM. SC,(1)
      MASS = EM .ASSEM. SC,(2)
C
C        PRINT STIFFNESS MATRIX AND MASS MATRIX
      PRINT(FORCE,DISP,,) STIFF
C
      PRINT(FORCE,ACCEL,,) MASS
C
C        GENERATE DYNAMICS MATRIX
C
      TOP,BOT  = STIFF .DEJOIN. (SC(6,1),1)
      K11,K12  = TOP .DEJOIN. (SC(6,1),0)
      K12T,K22  = BOT.DEJOIN. (SC(6,1),0)
      K22I =  -K22 .INVERS.
      KR1  = K22I .MULT. K12T
      KR2  = K12  .MULT. KR1
      KR   = K11  .ADD.  KR2
      IDENT = K11 .IDENTR.
      KR1T = KR1 .TRANSP.
      GAMT  = IDENT .ADJOIN. KR1T
      GAM   = GAMT .TRANSP.
      MR1  = GAMT .MULT. MASS
      MR  = MR1 .MULT. GAM
      KRI = KR .INVERS.
      DYNAM = KRI .MULT. MR
C
C        FIND E-VALUES, E-VECTORS, NORMAL MODES,
C        FREQUENCIES AND PRINT
C
      EVALUE,EVECT,, = DYNAM, .EIGEN1. SC
C
      TRC1, TR2 = TR .DEJOIN. (SC(8,1),1)
      TRC,TR1 = TRC1 .DEJOIN. (SC(5,1),1)
      GPPRINT (3,,,,SC,TR1) EVECT,EVALUE
C
C        GENERATE STIFFNESS AND GENERALIZED MASS
C        MATRICES AND PRINT
C
      KGEN1 = EVECT.TMULT.KR
      KGEN = KGEN1.MULT.EVECT
      MGEN1 = EVECT.TMULT.MR
      MGEN = MGEN1.MULT.EVECT
C
      PRINT(,,,) MGEN,KGEN,DYNAM,KR,MR
```

Figure II-8. Dynamic Agendum With Condensation

h. Agendum Level Abstraction Instructions

An Agendum Level abstraction capability has been incorporated into the MAGIC II System. The abstraction instructions for any type of analysis will be automatically generated for the user when he specifies the corresponding option on the $INSTRUCTION card. The Agendum library is expandable and the addition of more abstraction instruction sequences (Agendum) only requires the updating of subroutine AGENDM, and of course the Agendum library itself. The use of an Agendum in no way restricts the User because he can include in his input deck his own abstractions to be merged with the selected Agendum.

Subroutine AGENDM controls the selection from the Agendum library of the abstraction instruction sequence requested on the $INSTRUCTION card. At present, this subroutine has the capability to select six Agendums, STATICS, STATICSC, STATICS2. DYNAMICS, DYNAMICSC and STABILITY. The programming procedure utilized to add additional options to the library is discussed in Appendix IX, Section III of the Programmer's Manual (Volume III).

The following examples are provided to explain typical usage of the Agendum Library.

The most important points to note from these examples are that an Agendum for any particular run may be modified by addition of additional instructions which are input by the User. However, these additional instructions can only be added to the end of any particular Agendum at the present time.

Examples of Agendum Usage

```
        CC1   CC7      CC16

(a)     $MAGIC
        $RUN           GO
        $INSTRUCTION   STATICS
        $SPECIAL
        [Report Form Input Deck for .USER04. Instruction]
        $END

(b)     $MAGIC
        $RUN
              INPUT    TAPE(OLD,1969)
              OUTPUT   TAPE(MAG,1970)
        $INSTRUCTION   DYNAMICS
              A=DYNAM.ADD.LMASS
              SAVE(MAG)DYNAM,LMASS,A
        $SPECIAL
        [Report Form Input Deck for .USER04. Instruction]
        $END
```

C. STRUCTURAL INPUT DATA

1. General Description

Significant portions of the labor and computer costs of structural analysis are occasioned by incomplete or improper specification of structural input data. In recognition of this, a number of features have been incorporated into the MAGIC System to assist in the confirmation of problem data prior to execution. The most important of these are the prelabeled input data forms which are an integral part of the MAGIC System. These input data forms contain a number of special features, e.g.:

(1) " MODAL" Options are provided which preset a table to a given set of values. This MODAL option may be used where indicated.

(2) " REPEAT" Options are provided which minimize the input data specified by the User. This REPEAT option may be used where indicated.

(3) The User exercises control options simply by placing an 'X' in a given location on a prelabeled input data form.

(4) The prelabeled input data forms have permanent label cards which automatically precede subsets of data thereby allowing flexibility in the arrangement of input decks.

(5) Zeros must be indicated where pertinent. Blanks are never zeros except where specifically indicated.

(6) Only prelabeled input forms associated with options that are exercised in any particular problem are needed. Data associated with options not exercised are simply omitted.

(7) A program option is provided to conduct a read and write of input data with execution suppressed. Output from the data read and write option includes the material properties derived from the Materials Library as well as tables completed by MODAL specification of data. This option is exercised by simply placing the prelabeled input data form designated as CHECK at the end of the input data deck.

The prelabeled input data forms are separable into four main categories; namely, Material Library, Control Data, Problem Data and Data Read and Write.

The Material Library Section is a particularly useful input feature of the MAGIC System. This library is a permanent data set available for interrogation by the system. Additions and/or deletions to the Material Library are executed by the MAGIC System. The updating of the Material Library may be conducted independently of program execution or as an integrated pre/post execution operation.

A library specification of material may include Elastic Constants, Coefficients of Thermal Expansion and Mass Density. Material anisotropy is assumed as well as temperature dependence. Provision is made for data at up to ten temperature levels. Linear interpolation is employed in interrogation of the material specification.

The number of entries in the Material Library need not be limited, though the time for interrogation is affected by the number of entries. Listings of the complete library or specified portions are conveniently available by program option.

The Control Section provides the User with controls on System parameters. A prelabeled input form is provided. Figure II-3 shows the prelabeled data form which pertains to System Control Information.

The Problem Data Section consists of the following input:

(1) Grid point coordinates

(2) Grid point pressures

(3) Grid point temperatures

(4) Rotational transformations

(5) Boundary conditions

(6) External loads

(7) Prescribed displacements

(8) Element input

(9) Dynamics information

The numerical input pertinent to the above problem data is presented in floating point and fixed point notations. In floating point notation, the decimal point is always shown on the input data and in fixed point notation the decimal is never shown. The floating point notation is applicable, for example, to measurable quantities such as loads, coordinates, etc. The fixed point notation is limited to whole numbers or integers such as grid point numbers.

In floating point notation, a number may be written in either the conventional manner or as a factor of 10^n; for example, the number 30 000 000 = 30 x 10^6 can be written as either 30 000 000 or 30.0 E6. For numerical input data (both fixed and floating point)

plus signs are not normally used. Negative numbers and negative exponents, however, must be preceded by a minus sign.

In the Problem Data Section, extensive use can be made of the MODAL and REPEAT options. Identical elements should be grouped in order to maximize the use of REPEAT options. Grid points should be numbered in such a manner that full advantage is taken of stiffness matrix banding.

The Data Read and Write Section is provided to conduct read and write of input data with primary calculations suppressed. This is exercised via the prelabeled input data form designated as CHECK.

It is recommended that this feature be used routinely to minimize execution against incorrect problem specifications. Reduction in costs and frequently, reduction in elapsed calendar time can be expected with disciplined use of this feature.

The input data package has been designed to minimize redundant information. As a consequence, consistency checks do not verify that the same information given at different times is in fact the same. Rather, these checks insure that prespecified types and quantities of data are consistent with the data of reference. For example, the specification of a certain type of analysis implies the need for associated items of data. Messages are printed corresponding to inconsistencies identified and execution is suppressed though complete Read and Write is attempted.

The procedure used in the preparation of the prelabeled data forms will now be explained in detail. The description will proceed by data sections. It is important to note that slashes (/) which appear on the prelabeled input data forms, instruct the Keypunch Operator to proceed to the next entry position on the input data form, or if all entries have been punched, to the next data section.

2. Title Section (Figure II-1)

A prelabeled input data form is provided for the TITLE Section and is shown in Figure II-1.

The first entry on the form is prelabeled REPORT and requires no information from the User. It is to be noted that this label card designated REPORT must be the first card for all data decks which use these prelabeled input data forms.

The second entry on the form is prelabeled TITLE and also requires no information from the User/

The third entry on the form concerns the Number of Title Cards which are to follow. This information appears in Columns 7-9 and is given in fixed point form.

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MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

REPORT (/)

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

1 2 3 4 5 6
TITLE (/)

7 8 9
(/) NUMBER OF TITLE CARDS

FIGURE II-1 TITLE DATA FORM

Alphameric description of the problem is placed on the following cards. The total number of these cards must be equal to the number which appears in Columns 7-9 of the third entry, (Number of Title Cards).

3. Material Tape Input Section (Figure II-2)

The Material Tape Input Section is used when a material is to be added, revised or deleted from the material tape. It can also be employed at the User's option to examine the contents of the tape or to obtain a summary of the materials which appear on the tape at the time the request is being made.

The labeled input data form provided for material tape entries, is shown in Figure II-2. The first entry on the form is prelabeled MATER and requires no input from the User.

The second entry on the form concerns the number of requests which are being made against the material tape. This information appears in Columns 7-9 of the second entry, and the User may make as many requests as desired against the material tape.

The third entry in the section contains the following detailed information as shown in the figure.

Request Number - (Cols. 7-9)

The total number of requests which are made against the material tape must be equal to the number of requests specified on the second entry of the form. It should be noted, however, that the first set of material data (Material Properties Table) is input before a second request is made.

Material Number - (Cols. 10-15)

The material number for a material which is to be added to the tape is chosen at the discretion of the User. If a number is chosen that corresponds to the number of a material which already appears on the tape, the new material will not be accepted unless the lock code associated with the new material is exactly the same as the lock code of the material which already appears on the tape. If this is the case the new material will be added to the tape and the material that formerly appeared there will be deleted. The material number can be any combination of alphameric characters.

Lock Code - (Cols. 16-17)

A lock code is associated with each material specification. Any User has access to the entire material library but modification of an existing material specification requires a prior knowledge of the lock code. The lock code is not disclosed by displays of the material library. As a consequence revision or deletion of any entry remains under the control of the initiator. The lock code may be any combination of alphameric characters.

Material Identification - (Cols. 18-41)

The material identification is left to the discretion of the User. It serves only to provide the analyst with a means of identifying the material and is not interrogated by the program.

Material Tape Input - (Cols. 42-50)

The information in columns 42 through 50 is mutually exclusive, that is, the User should enter no more than one 'X' in columns 42-50. If the User enters more than one 'X' in columns 42-50, then only the first choice will be retained and the others will be ignored by the program. An 'X' in any of columns 42 through 46 will indicate that a material is to be added or revised. Whenever this is the case, a summary of the material tape will be printed and the material table for the new or revised material will be displayed. When an 'X' is placed in column 47, the specified material will be deleted from the material tape and a summary of the new tape will be printed. Columns 48 through 50 are used to interrogate the tape to ascertain what it contains. If an 'X' is placed in column 48, 49 or 50, the existing material tape will be printed with no update of the material tape taking place.

Number of Material Points - (Cols. 51-52)

The number entered in these columns determines the number of material (temperature) points which will appear in the material properties table. At the present time, the number of allowable material points is ≤ 9.

Material Properties Table

All the data input to the Material Properties Table, appears in floating point form. If the material in question is isotropic, only the Modulus of Elasticity, E, Poisson's Ratio, ν_{ij}, and the coefficient of thermal expansion, α, are needed for each temperature point. The value of the modulus of shearing rigidity, G, is calculated by the program.

For an orthotropic material there are three cards required for each temperature point entered. For these cases, the value of ν_{ij} must be entered by the User for each of the x, y, and z directions.

IMPORTANT REMINDERS:

(1) Poisson's Ratio, ν_{ij} is defined as strain induced in the j direction by a stress in the i direction.

(2) For isotropic materials Poisson's ratio, ν_{ij}, must lie between 0.0 and 0.5 ($0.0 \leq \nu_{ij} \leq 0.5$). Violation of this rule causes the material properties matrix [E] to become non-positive definite.

(3) A maximum of nine (9) material (temperature) points may be input per material and a minimum of 1 must appear for a material of constant temperature.

(4) Certain limits on material properties must be observed. These limits are as follows:

(a) Young's Modulus (E)	$E > 1.0$
(b) Thermal Coefficient (α)	$-1.0 < \alpha < 1.0$
(c) Shear Modulus (G)	$G > 1.0$

(5) If it is desired to bypass the internal check of input material properties an asterisk (*) is placed in Column 10, the first column of the material number in the third entry.

(6) The Number of Requests and/or Revisions of Material Tape must be specified on the System Control Information Data Form (Figure II-3).

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MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

M	A	T	E	R	
1	2	3	4	5	6

(/)

7	8	9

No. of Requests (/)

MATERIAL TAPE INPUT

Request Number	MATERIAL NUMBER	Lock Code	MATERIAL IDENTIFICATION	Isotropic	Orthotropic	Plastic Isotropic	Plastic Orthotropic	Add Plastic	Delete Material	Print Tape	Print Mat'l. Table	Print Mat'l. Summary	Number of Mat'l. Pts.	Number of Plastic Pts.	MASS DENSITY
7–9	10–15	16–17	18–41	42	43	44	45	46	47	48	49	50	51–52	53–54	55–64

(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE	Direction	YOUNGS MODULI	Direction	POISSONS RATIOS	Direction	COEF. OF THERMAL EXPANSION	Direction	RIGIDITY MODULI	
13–22		23–32		33–42		43–52		53–62	
	E_x		ν_{xy}		α_x		G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

FIGURE II-2 MATERIAL TAPE INPUT DATA FORM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MATERIAL PROPERTIES TABLE
(continued)

TEMPERATURE (13 4 5 6 7 8 9 20 1 2)		YOUNGS MODULI (23 4 5 6 7 8 9 30 1 2)		POISSONS RATIOS (33 4 5 6 7 8 9 40 1 2)		COEF. OF THERMAL EXPANSION (43 4 5 6 7 8 9 50 1 2)		RIGIDITY MODULI (53 4 5 6 7 8 9 60 1 2)	
	E_x		ν_{xy}		α_x		G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

Page ________ of ________

FIGURE II-2 CONCLUDED

4. System Control Information Section (Figure II-3)

The prelabeled System Control Information data form is shown in Figure II-3. The first entry on the form is prelabeled SYSTEM, and requires no input from the User.

The second entry on the form contains the eleven (11) items of information defined in the list which follows. All items of information are written in fixed point notation with the exception of Item 11 which is written in floating point form.

(1) Number of System Grid Points - (Cols. 1-6)

The number of System Grid Points is equal to the largest integer number which participates in element connection (assembly). This number is best obtained from a scan of the completed Element Control Data Cards. These will be described in detail in a subsequent data section.

(2) Number of Input Grid Points - (Cols. 7-12)

The number of input grid points is equal to the integer number of grid points for which coordinates are data specified. This number is best obtained from a scan of the completed Grid Point Coordinate Input Section. The number entered is equal to the total number of grid points for which coordinates are specified. (Maximum allowable = 999).

(3) Number of Degree of Freedom/Grid Point - (Cols. 13-14)

The number of degrees of freedom per grid point is dictated by the type of finite elements which are being used for any particular analysis.

(a) Three (3) Degrees of Freedom per Grid Point

1 - Triangular Cross-Section Ring Element

2 - Trapezoidal Cross-Section Ring (And Core) Element

(b) Six (6) Degrees of Freedom per Grid Point

1 - Frame Element

2 - Quadrilateral Shear Panel Element

3 - Quadrilateral Thin Shell Element

4 - Triangular Thin Shell Element

5 - Incremental Frame Element

6 - Quadrilateral Plate Element

7 - Triangular Plate Element

(c) Nine (9) Degrees of Freedom per Grid Point

Toroidal Thin Shell Ring Element

At the present time, only elements that are characterized by the same number of degrees of freedom per grid point can be used together in any one analysis. For example, the toroidal thin shell ring and frame elements are not compatible.

(4) Number of Load Conditions - (Cols. 15-16)

The Number of Load Conditions is equal to the number of external load conditions that are applied to the system. Note that external loads are not to be confused with element applied loadings such as temperature and pressure.

At least one load condition is required for every analysis even if there are no external loads applied to the system. An entry must be made in the External Loads Section even for zero loads.

At the present time, the maximum number of external load conditions allowed is one hundred (100).

(5) Number of Initially Displaced Grid Points - (Cols. 17-22)

Initially displaced grid points are present only if function minimization (or other iterative technique) is employed in the analysis. In the present MAGIC System no provision is made for initially displaced grid points. Therefore, no entries should be made in this location.

(6) Number of Prescribed Displaced Grid Points -(Cols. 23-28)

Applied loadings may be prescribed in terms of non-zero displacement values either one displacement load condition or the NL displacement load conditions can be accommodated per execution. NL is defined as the total number of external load conditions in any given analysis. The number of prescribed displaced grid points is the number of grid points that are assigned known values of displacement other than zero. If there are no prescribed non-zero grid point displacements, this entry is ignored by the User.

(7) Number of Grid Point Axes Transformation Systems - (Cols. 29-30).

The number of grid point axes transformation systems required by the problem is entered in this location. If grid point axes are being used in an analysis, the number of systems employed is best obtained from a scan of the completed Rotational Transformation (GRAXES or TRANS) Sections which will be described in a following section. If there are no grid point axes transformations employed, this entry is ignored by the User.

(8) Number of Elements - (Cols. 31-36)

The total number of elements to be employed in the analysis is entered in this location. The allowable number of elements is equal to 3000.

(9) Number of Requests and/or Revisions of Material Tape- (Cols. 37-38)

The total number of requests and/or revisions being made against the material tape for any particular run are entered in this location. This number must be equal to the number which appears on the second entry under Section II, Material Tape Input Section (Figure II-2).

(10) Number of Input Boundary Condition Points - (Cols. 39-44)

The Number of Input Boundary Condition Points is equal to the number of exceptions to the MODAL card associated with the Boundary Condition Section. This number is best obtained by scanning the completed Boundary Condition Section and counting the total number of grid points which are entered as Listed Input.

(11) T_o For Structure (With Decimal Point) - (Cols. 45-52)

The number entered in this location is equal to the equilibrium temperature for the structure to be analyzed. If a value is not entered in this location, an ambient temperature of zero degrees will be assumed.

If a thermal stress analysis is being run, then the ambient temperature must be entered if different than zero degrees.

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

	S Y S T E M (/) 1 2 3 4 5 6
1. Number of System Grid Points	1 2 3 4 5 6
2. Number of Input Grid Points	7 8 9 10 11 12
3. Number of Degrees of Freedom/Grid Point	13 14
4. Number of Load Conditions	15 16
5. Number of Initially Displaced Grid Points	17 18 19 20 21 22
6. Number of Prescribed Displaced Grid Points	23 24 25 26 27 28
7. Number of Grid Point Axes Transformation Systems	29 30
8. Number of Elements	31 32 33 34 35 36
9. Number of Requests and/or Revisions of Material Tape.	37 38
10. Number of Input Boundary Condition Points	39 40 41 42 43 44
11. T_o For Structure (With Decimal Point)	45 46 47 48 49 50 51 52 (/)

FIGURE II-3 SYSTEM CONTROL INFORMATION DATA FORM

5. <u>Print Control Section (Figure II-4)</u>

The labeled input data form provided for the Print Control Section is shown in Figure II-4.

On this form provision is made for printing the following items:

(1) Assembly - Stiffness - (Col. 1)

(2) Inverse - (Col. 2)

(3) Triangularized - Stiffness - (Col. 3)

(4) Displacements - (Col. 4)

(5) Intermediate Function Minimization (Col. 5)

This section is not applicable in the present MAGIC System. It is included because it is anticipated that these and other options will be provided in this manner in future MAGIC Systems. The present print control options reside in the abstraction instruction capability associated with the System.

It is noted, however, that output from the Structural Monitor records the input data problem description as well as optional intermediate results. These optional intermediate results can be obtained using the element matrix print options which are described in the Element Control Section.

6. <u>Grid Point Coordinate Section (Figure II-5)</u>

The labeled input data form provided for the Grid Point Coordinate Section is shown in Figure II-5. The first entry is prelabeled COORD and requires no input from the User.

The second and following entries contain information pertaining to the grid point numbers and their corresponding coordinates as follows.

<u>Coordinate System Definition - (Col. 5)</u>

For each grid point entered in the grid point coordinate section, the code corresponding to the coordinate system employed for a particular grid point should be entered. An R in Column 5 indicates that the coordinates for that particular grid point are entered in a Cartesian system. A C indicates entry in a cylindrical system and an S in column 5 indicates an entry in a spherical system. If column 5 is left blank then the program assumes that grid point data is input in the Cartesian system.

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

PRINT OPTIONS

P	R	I	N	T		(/)
1	2	3	4	5	6	

PLACE 'X' IN BOX OPPOSITE DESIRED PRINT

1. Assembly – Stiffness	1	
2. Inverse – Stiffness	2	
3. Triangularized – Stiffness	3	
4. Displacements	4	
5. Intermediate Function Minimization	5	(/)

FIGURE II-4 PRINT CONTROL DATA FORM

It is possible to mix coordinate systems since the program converts all coordinates to the Cartesian system before beginning an analysis. It should also be noted that the output such as displacements, and element forces will be referenced to a Cartesian global system even though the input coordinates may be in a different system. If the User desires output in a system other than the Cartesian global, the Grid Point Axes Transformation Section should be consulted.

Grid Point Number - (Cols. 7-12)

Grid points are entered as fixed point numbers and can be entered in any sequence desired. The maximum number of input grid points allowed is equal to 999. The total number of grid points entered in this section must be called out on the System Control Information Data Form in the entry reserved for the Number of Input Grid Points (Figure II-3).

Grid Point Coordinates - (Cols. 13-42)

Grid point coordinates are entered as floating point numbers. For each grid point number entered, a corresponding set of coordinates must also be entered.

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MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6	
C	O	O	R	D		(/)

GRIDPOINT COORDINATE

	COORD. INPUT	S
SYSTEM	RECTANGULAR	R/Δ
	CYLINDRICAL	C
	SPHERICAL	S

Δ = BLANK

S		Grid Point Number	DIRECTIONS: X – R	Y – θ	Z – Z	
5	6	7 8 9 10 1 2	13 4 5 6 7 8 9 20 1 2	23 4 5 6 7 8 9 30 1 2	33 4 5 6 7 8 9 40 1 2	
						(/)
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If coordinate information must be continued on second sheet, user MUST delete Coord. Label Card from second sheet.

FIGURE II-5 GRID POINT COORDINATE DATA FORM

7. Grid Point Pressure Section (Figure II-6)

Pressure loading is considered as element applied loading and is transformed into consistent energy equivalent grid point loads within the MAGIC System. For convenience to the User, the pressures are input at each grid point. In order to accomplish this, a labeled input data form is provided for the Grid Point Pressure Section. This form is shown in Figure II-6.

In this section the User may employ two time saving devices.

(1) MODAL - The MODAL option automates the specification of recurring values within a subset of input data. This feature enables data-prescribed initialization of tables. Explicit data requirements are thereby limited to specification of exceptions to the modal initialization.

(2) REPEAT - A Repeat option is available which allows the User to retain data from a previous point for the indicated point.

The first entry on the form is prelabeled PRESS and requires no input from the User. The second entry on the form is the MODAL entry. MODAL is prelabeled in Columns 1-5 of this entry. Columns 13-42 are reserved for input pressures. This MODAL option allows the User to input a pressure value or set of pressure values (depending on the finite element employed) which the system applies to every grid point unless otherwise indicated by a separate entry on the grid point cards which follow the MODAL entry.

In the present MAGIC System, a maximum of three pressure values may be input per grid point. These pressures (entered in floating point notation) are interpreted according to the element which is being employed in the analysis.

The third and following entries in the section contain information pertaining to the Grid Point Numbers, Repeat Option and corresponding pressure values as follows:

Grid Point Number - (Cols. 7-11)

(1) Grid points are entered as fixed point numbers.

(2) Grid points can be entered in any sequence desired.

(3) Along with each grid point a maximum of three pressure values can be input. The pressure entry is a function of the type of element or elements employed in the analysis (See Element Control Section).

Repeat - (Col. 12)

The repeat option allows the User to repeat re-occurring pressure from grid point to grid point. This is accomplished in the following manner. If pressures at a number of grid points are identical, the User enters the grid point number and associated pressure or pressures for the first grid point at which the pressure or pressures are acting. For the following points with identical pressures, just the grid point number (Col. 7-11) and an 'X' in the Repeat (Col. 12) need be entered.

REMEMBER:

(1) For a problem with equal pressures at all grid points, only the MODAL entry is required.

(2) The Repeat option can be used effectively for sets of grid points which have identical pressures.

(3) For a problem where pressure loading is not pertinent, the User simply ignores the Grid Point Pressure Section.

(4) Pressures associated with each finite element are completely described in the Element Control Section.

(5) Pressure loadings are element related and are not to be confused with External Loads.

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

GRID POINT PRESSURES

1	2	3	4	5	6	
P	R	E	S	S		(/)

1	2	3	4	5	6
M	O	D	A	L	

PRESSURES			
P1	P2	P3	
13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42	
			(/)

Grid Point Number	Repeat	P1	P2	P3	
7 8 9 10 11	12	13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42	
					(/)
					(/)
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FIGURE II-6 GRID POINT PRESSURE DATA FORM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

GRID POINT PRESSURES
(continued)

Grid Point Number					Repeat	P_1										P_2										P_3										
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	
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FIGURE II-6 CONCLUDED

8. Grid Point Temperature Section - (Figure II-7)

Temperature loading is considered as element applied loading and is transformed into consistent energy equivalent grid point loads according to element type. For convenience to the User, the temperature values (or temperature gradients) are input at each grid point. In order to accomplish this, a labeled input data form is provided for the Grid Point Temperature Section. In this section (as in the Grid Point Pressure Section) the User may employ two time saving devices.

(1) MODAL - The MODAL option automates the specification of recurring values within a subset of input data. This feature enables data-prescribed initialization of tables. Explicit data requirements are thereby limited to the specification of exceptions to the MODAL initialization.

(2) REPEAT - A Repeat option is available which allows the User to retain data from a previous point for the indicated point.

The prelabeled input data form provided for the Grid Point Temperature Section is shown in Figure II-7. The first entry on the form is prelabeled TEMP and requires no input from the User.

The second entry on the form is the MODAL entry. MODAL is prelabeled in Columns 1-5 of this entry. Columns 13-42 are reserved for input temperatures (or temperature gradients). The MODAL option allows the User to input a temperature, or temperature gradient, (depending on the finite element employed) which the system applies to every grid point unless otherwise indicated by a separate entry on the grid point cards which follow the MODAL entry.

The second and following entries in the section contain information pertaining to the Grid Point Numbers, Repeat Option. and corresponding temperature values (or gradients) as follows:

Grid Point Number - (Cols. 7-11)

(1) Grid points are entered as fixed point numbers.

(2) Grid points can be entered in any sequence desired.

Repeat - (Col. 12)

The repeat option allows the User to repeat reoccurring temperatures (or gradients) from grid point to grid point. This is accomplished in the following manner. If temperatures at a number of grid points are identical, the User enters the grid point number and associated temperature data for the first grid point. For the following points having the same temperature data, just the grid point number (Col. 7-11) and an 'X' in the Repeat (Col. 12) need be entered.

From Figure II-7 it is noted that provision is made for three values of temperature (or temperature gradients) depending on what finite element is being used in the analysis. A complete description of each element along with appropriate instructions for the input of temperatures and temperature gradients will be presented in the Element Control Section.

REMEMBER:

(1) For a problem with equal temperatures at all grid points, only the MODAL entry is required.

(2) The Repeat option can be used effectively for sets of grid points which have the same temperatures.

(3) Remember to specify T_o on the System Control Information Data Form (Figure II-3).

(4) For a problem where temperature loading is not pertinent the User simply ignores the Grid Point Temperature Section.

(5) Temperature loadings are element related and are not to be confused with External Loads.

(6) The temperatures input in the Section must be consistent with the units of the coefficient of thermal expansion, α , which was input in the Material Tape Input Section (Figure II-2).

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

GRID POINT TEMPERATURES

1	2	3	4	5	6	
T	E	M	P			(/)

	TEMPERATURES			
	T1	T2	T3	
1 2 3 4 5 6	13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42	
M O D A L				(/)

Grid Point Number	Repeat	T1	T2	T3	
7 8 9 10 11	12	13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42	
					(/)
					(/)
					(/)
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FIGURE II-7 GRID POINT TEMPERATURE DATA FORM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

GRID POINT TEMPERATURES
(continued)

Grid Point Number	Repeat	T_1	T_2	T_3	
7 8 9 10 11	12	13 4 5 6 7 8 9 20 1 2	23 4 5 6 7 8 9 30 1 2	33 4 5 6 7 8 9 40 1 2	
					(/)
					(/)
					(/)
					(/)
					(/)
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					(/)
					(/)

FIGURE II-7 CONCLUDED

9.a. Rotational Transformations Section - Input Matrices - (Figure II-8a)

In general, a reference axis system is associated with each grid point. This Local System ($\overline{X}$, $\overline{Y}$, $\overline{Z}$) may be specified in two ways. Firstly, it can be specified in terms of a 3 x 3 transformation relative to Global Axes (X, Y, Z). Alternatively, axes for a grid point may be specified by a set of coordinate points. The three by three transformation relative to Global Axes is then generated internally and exhibited in the edited display of problem description data. This feature enables treatment of boundary constraints arbitrarily oriented with respect to Global Axes. It also allows displacement output to be displayed in convenient Local Systems (e.g. shell midsurface and normal directions).

This section deals with the case in which the User inputs the three by three transformation matrices relative to Global Axes.

The labeled input data form provided for this section is shown in Figure II-8a. The first entry is prelabeled TRANS and requires no input from the User. The second and subsequent entries contain the following items of information.

System Number - (Cols. 7-9)

The System Number is entered as a fixed point number. This number can be from 1 to n where n is the number of Local Systems which are being transformed. The value of n must be called out on the System Control Information Data Form (Figure II-3).

Number of Applicable Grid Points - (Cols. 10-12)

The entry made in this position is equal to the number of grid points which are contained in the Local System being transformed. This number is entered as a fixed point number.

The next entries made by the User pertain to the applicable grid points themselves. The number of grid points entered must be equal to the number which was entered in the Number of Applicable Grid Points Location (Cols. 10-12).

Applicable Grid Points - (Cols. 7-51)

There is provision made for a maximum of 15 applicable grid points per system number in this location. Each grid point is contained in a three column field and is entered as a fixed point number. If more than 15 grid points are applicable to one transformation, the remaining points must be defined under additional systems.

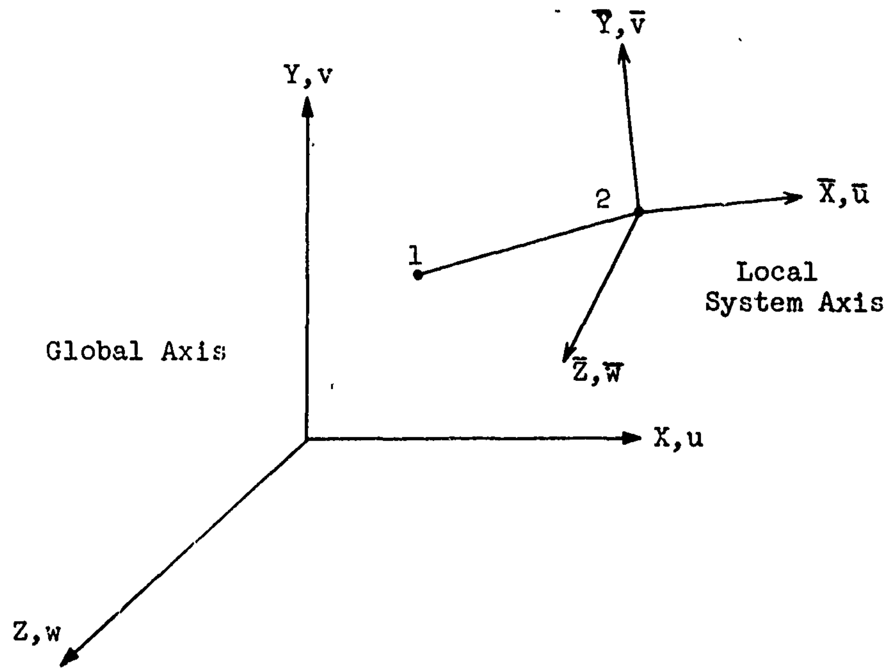
Transformation Matrix

The following entries are the elements of the three by three transformation matrix itself. The transformation matrix is of the form

$$\{X_G\} = [T] \{X_L\}$$

where the $\{X_G\}$ refers to Global (X, Y, Z) coordinate Vector and the $\{X_L\}$ refers to Local System ($\overline{X}$, $\overline{Y}$, $\overline{Z}$) coordinate Vector. The transformation matrix is of the form:

$$[T] = \begin{bmatrix} \lambda_x & u_x & v_x \\ \lambda_y & u_y & v_y \\ \lambda_z & u_z & v_z \end{bmatrix}$$

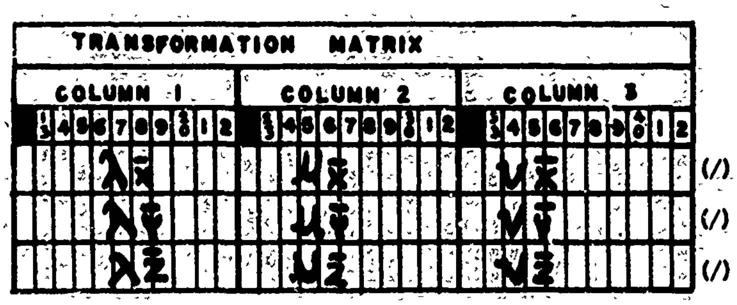


$$\lambda_{\bar{x}} = \text{Cos}\ \theta_{x\bar{x}} \qquad u_{\bar{x}} = \text{Cos}\ \theta_{y\bar{x}} \qquad v_{\bar{x}} = \text{Cos}\ \theta_{z\bar{x}}$$

$$\lambda_{\bar{y}} = \text{Cos}\ \theta_{x\bar{y}} \qquad u_{\bar{y}} = \text{Cos}\ \theta_{y\bar{y}} \qquad v_{\bar{y}} = \text{Cos}\ \theta_{z\bar{y}}$$

$$\lambda_{\bar{z}} = \text{Cos}\ \theta_{x\bar{z}} \qquad u_{\bar{z}} = \text{Cos}\ \theta_{y\bar{z}} \qquad v_{\bar{z}} = \text{Cos}\ \theta_{z\bar{z}}$$

and the input to the prelabeled input data form is as follows:



REMEMBER:

(1) Total number of Systems which are being transformed must be set forth on the Systems Control Information Data Form (Figure II-3).

(2) In this section the transformation matrices are input by the User. In the following section, titled GRAXES the transformation matrices are calculated internally by the MAGIC System.

T	R	A	N	S		(/)
1	2	3	4	5	6	

SYSTEM NUMBER			Number of Applicable Grid Points			
7	8	9	10	11	12	
						(/)

APPLICABLE GRID POINTS: 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Columns: 7 8 9 10 1 2 3 4 5 6 7 8 9 20 1 2 3 4 5 6 7 8 9 30 1 2 3 4 5 6 7 8 9 40 1 2 3 4 5 6 7

SYSTEM NUMBER			Number of Applicable Grid Points			
7	8	9	10	11	12	
						(/)

APPLICABLE GRID POINTS: 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Columns: 7 8 9 10 1 2 3 4 5 6 7 8 9 20 1 2 3 4 5 6 7 8 9 30 1 2 3 4 5 6 7 8 9 40 1 2 3 4 5 6 7

SYSTEM NUMBER			Number of Applicable Grid Points			
7	8	9	10	11	12	
						(/)

APPLICABLE GRID POINTS: 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Columns: 7 8 9 10 1 2 3 4 5 6 7 8 9 20 1 2 3 4 5 6 7 8 9 30 1 2 3 4 5 6 7 8 9 40 1 2 3 4 5 6 7

SYSTEM NUMBER			Number of Applicable Grid Points			
7	8	9	10	11	12	
						(/)

APPLICABLE GRID POINTS: 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Columns: 7 8 9 10 1 2 3 4 5 6 7 8 9 20 1 2 3 4 5 6 7 8 9 30 1 2 3 4 5 6 7 8 9 40 1 2 3 4 5 6 7

SYSTEM NUMBER			Number of Applicable Grid Points			
7	8	9	10	11	12	
						(/)

APPLICABLE GRID POINTS: 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Columns: 7 8 9 10 1 2 3 4 5 6 7 8 9 20 1 2 3 4 5 6 7 8 9 30 1 2 3 4 5 6 7 8 9 40 1 2 3 4 5 6 7

FIGURE II-8a ROTATIONAL TRANSFORMATION (INPUT MATRICES) DATA FORM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ROTATIONAL TRANSFORMATIONS
(INPUT MATRICES)

ID POINTS									
6	7	8	9	10	11	12	13	14	15

TRANSFORMATION MATRIX		
COLUMN 1	COLUMN 2	COLUMN 3

ID POINTS									
6	7	8	9	10	11	12	13	14	15

TRANSFORMATION MATRIX		
COLUMN 1	COLUMN 2	COLUMN 3

ID POINTS									
6	7	8	9	10	11	12	13	14	15

TRANSFORMATION MATRIX		
COLUMN 1	COLUMN 2	COLUMN 3

ID POINTS									
6	7	8	9	10	11	12	13	14	15

TRANSFORMATION MATRIX		
COLUMN 1	COLUMN 2	COLUMN 3

ID POINTS									
6	7	8	9	10	11	12	13	14	15

TRANSFORMATION MATRIX		
COLUMN 1	COLUMN 2	COLUMN 3

ICES) DATA FORM

1220

9.b. Rotational Transformations Section - General Trans. Matrices (Figure II-8b)

A reference axis system is normally associated with each grid point. This Local System ($\bar{X},\bar{Y},\bar{Z}$) may be specified in two ways. Firstly, it can be specified in terms of a 3 x 3 transformation relative to Global Axes (X,Y,Z). Alternatively, axes for a grid point may be specified by a set of coordinate points. The three by three transformation relative to Global Axes is then generated internally and exhibited in the edited display of problem description data. This feature enables treatment of boundary constraints arbitrarily oriented with respect to Global Axes. It also allows displacement output to be displayed in convenient Local Systems (e.g. shell midsurface and normal directions).

This section deals with the case in which the transformation matrices are generated internally by the MAGIC System based on instructions supplied by the User.

The labeled input data form provided for this section is shown in Figure II-8b. The first entry is prelabeled GRAXES and requires no information from the User. The second and subsequent entries contain the following items of information.

System Number - (Cols. 7-9)

The grid point triad System Number is an integer identification code which enables convenient and explicit reference to particular grid point axes transformations of the form

$$\{X_G\} = [T] \quad \{X_L\}$$

$\{X_G\}$ = Global Coordinate Vector

$\{X_L\}$ = Local System Coordinate Vector

$[T]$ = Transformation Matrix

Local Axis Direction - (Cols. 10-12)

A grid point axis system is described by specifying the identification numbers of two grid points which lie along one axis together with the identification number of a gridpoint, which lies in one of the Local coordinate planes. The integer number '1' is placed in Column 10, 11, or 12, corresponding to the respective definition of the $\bar{X}$, $\bar{Y}$, or $\bar{Z}$ axis by two coordinate points.

Plane Definition Grid Point Numbers - (Cols. 13-24)

The grid point number column 1 and 2 identify the two grid points which lie along an axis of the grid point coordinate system. The positive direction is assumed from 1 toward 2. The coordinate plane (in which the coordinate point associated with the grid-point column labeled 3 resides), depends upon the axis defined by the first two points. The interpretation is as follows:

(1) If points 1 and 2 define the $\bar{X}$-axis then point 3 lies in the $(\bar{X},\bar{Y})$ plane.

(2) If points 1 and 2 define the $\bar{Y}$-axis then point 3 lies in the $(\bar{X},\bar{Y})$ plane.

(3) If points 1 and 2 define the $\bar{Z}$-axis then point 3 lies in the $(\bar{X},\bar{Z})$ plane.

Applicable Grid Point Numbers - (Cols. 25-69)

This data specifies the list of grid points associated with the grid point axis coordinate system identification number. If the list length exceeds the available space on the first line, then the remaining points must be redefined under additional Systems.

REMEMBER:

(1) Total number of Systems which are being transformed must be set forth on the Systems Control Information Data Form (Figure II-3).

(2) In this section the transformation matrices are generated internally by the System. In the preceding section entitled TRANS the transformation matrices were input by the User.

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MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

G	R	A	X	E	S	(/)
1	2	3	4	5	6	

ROTATIONAL TRANSFORMATIONS
(Generate Transformation Matrices)

SYS. NO.	Local Axis Direction			Plane Definition Grid Point Numbers			APPLICABLE GRID POINT NUMBERS															
	X	Y	Z	1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
7 8 9	10	11	12	13 4 5 6	7 8 9 20	1 2 3 4	5 6 7	8 9 30	1 2 3	4 5 6	7 8 9	40 1 2	3 4 5	6 7 8	9 50 1	2 3 4	5 6 7	8 9 60	1 2 3	4 5 6	7 8 9	
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FIGURE II-8b ROTATIONAL TRANSFORMATION (GENERATE TRANS. MATRICES) DATA FORM

10. Dynamics Section (Figure II-9)

The labeled input data form provided for the calculation of eigenvalues and eigenvectors using the .EIGEN 1. abstraction instruction is shown in Figure II-9. The first entry on the form is prelabeled DYNAM and requires no input from the User.

The second entry on the form contains the seven (7) items of information defined in the list which follows. All items of information are entered in fixed point notation, with the exception of Item 2 (Convergence Criteria).

(1) Number of Eigenvalues Requested - (Cols. 1-2)

The number of eigenvalues desired for a particular analyses is entered in this location. The maximum number of eigenvalues requested for any particular run is equal to twenty (20).

(2) Convergence Criteria - (Cols. 3-14)

The convergence criteria desired for each eigenvector is entered in Columns 3-14. The default option is 0.001. The program will automatically perform a maximum of 500 iterations (unless otherwise specified in Item (3) below) with this criteria trying to obtain convergence. If convergence isn't obtained in 500 iterations, the criteria is automatically relaxed to 0.002 and the procedure is repeated. This procedure will be performed a maximum of ten times until the final criteria is 0.01. If convergence hasn't been obtained at this level the program will automatically terminate with exploratory diagnostic messages.

(3) Maximum Number of Iterations - (Cols. 15-17)

The desired maximum number of iterations per convergence criteria for each mode is entered in Columns 15 thru 17. If an entry is not made in this location, the default will be 500 iterations.

(4) Debug Iteration Print (Col. 18)

If the User desires a print out of each iteration step, in the analysis sequence a '1' is entered in Column 18. If iteration print is not desired, Column 18 is left blank or a zero is entered.

(5) First Normalizing Element for Print (Cols. 19-22)

If the User desires eigenvector normalization, on some value other than the largest the option in Cols. 19-22 is used. If this option is to be used, the reduced degree-of-freedom on which the normalization is desired is entered.

(6) Second Normalizing Element for Print (Cols. 23-26)

If the User desires a second normalization on another degree-of-freedom, then the reduced degree-of-freedom on which this normalization is desired is entered in Columns 23-26.

It is to be noted that whether options (5), or (5) and (6) are activated or not, the User still obtains a print of the eigenvector normalized on the largest value contained in that vector.

(7) Control for Guess Vector Iteration Start (Col. 27)

Two types of iteration are available in the .EIGEN1. Instruction Package. Column or row iteration can be performed. If the User desires a row iteration start, a '1' is entered in Column 27. The normal procedure is to utilize Column iterations. For this option a zero is entered in Column 27 or it is left blank.

It is to be noted that the DYNAM Section is utilized to interrogate the .EIGEN1. abstraction for both vibration and stability analyses. In stability analyses, usually only the first buckling mode is of interest while in vibration analyses the first five or maybe ten modes are of interest depending on the problem being analyzed.

DYNAMICS INFORMATION

D	Y	N	A	M		(/)
1	2	3	4	5	6	

1. Number of Eigenvalues Requested (Less than or Equal to 20) — columns 1 2

2. Convergence Criteria (Floating Point) (Default Option - 0.001) — columns 3 4 5 6 7 8 9 10 11 12 13 14

3. Maximum Number of Iterations (Default Option - 500 Iterations) — columns 15 16 17

4. Debug Iteration Print
   Iteration Print ON = 1
   Iteration Print OFF = 0
   (Default Option - Print OFF) — column 18

5. First Normalizing Element for Print (Default Option - No First Normalization) — columns 19 20 21 22

6. Second Normalizing Element for Print (Default Option - No Second Normalization) — columns 23 24 25 26

7. Control for Guess Vector Iteration Start
   Column Iteration Start = 0
   Row Iteration Start = 1
   (Default Option - Column Iteration Start) — column 27 (/)

Figure II-9 Dynamics Control Information Data Form

11. Boundary Condition Section (Figure II-10)

The labeled input data form provided for the Boundary Condition Section is shown in Figure II-10. Three types of input codes define the types of displacement allowed:

1. Statics

   (a) 0 = No Displacement Allowed,

   (b) 1 = Unknown Displacement and

   (c) 2 = Known (Prescribed) Displacement.

The input code designated, '2', Known Displacement, pertains to displacement loading. If displacement loading is present in an analysis, the degrees of freedom which have known values of displacement are designated with the input code '2 . A separate prelabelled input data form designated as the prescribed Displacement Section is provided so that the User may input the values of the known (prescribed) displacements associated with these degrees of freedom. This form will be described in detail in the following section.

2. Statics With Condensation

   (a) 0 = No displacement allowed,

   (b) 1 = Unknown Displacement and

   (c) 2 = Displacement Degree of Freedom to be Condensed (Eliminated) From the Stiffness Matrix Which Define the System.

The input code designated '2' pertains to a degree-of-freedom that is to be condensed from the system. This procedure is used in conjunction with the abstraction instructions designated as STATICSC which were described in detail previously.

3. Dynamics With Condensation

   (a) 0 = No displacement allowed,

   (b) 1 = Unknown displacement and

   (c) 2 = Displacement degree-of-freedom to be condensed (eliminated) from the stiffness and mass matrices which define the system.

The input code designated '2' pertains to a degree-of freedom that is to be condensed from both the stiffness and mass matrices which define the system. This procedure is used in conjunction with the abstraction instructions designated as DYNAMICSC which were described in detail previously.

With regard to the Boundary Condition Section, the User may employ two time saving devices.

(1) MODAL - The MODAL option automates the specification of reoccurring values within a subset of input data. This feature enables data-prescribed initialization of tables. Explicit data requirements are thereby limited to specification of exceptions to the MODAL initialization.

(2) REPEAT - A REPEAT option is available which allows the User to retain data from a previous point for the indicated point.

The first entry on the Boundary Condition form is prelabeled BOUND and requires no input from the User. The second entry on the form is the MODAL entry. MODAL is prelabeled in columns 1-5 of this entry. Columns 13-21 are reserved for boundary conditions. The MODAL option allows the User to input a set of boundary conditions which the system applies to every grid point unless otherwise indicated by a separate entry on the grid point cards (Listed Input) which follow the MODAL entry.

A total of nine degrees of freedom per point has been provided on the prelabeled input forms. Three translation degrees of freedom (u, v, w), three rotations (θ_x, θ_y, θ_z) and three generalized degrees of freedom (1, 2, 3). The total number of degree of freedom entries per point is a function of the type being employed in the analysis.

(1) Triangular Cross-Section Ring, Trapezoidal Cross-Section Ring (Core) - Three Degree of Freedom Entries per point: Corresponding Displacements (u, v, w).

(2) Frame Element Incremental Frame Element, Quadrilateral Shear Panel, Quadrilateral and Triangular Thin Shell Elements, Quadrilateral and Triangular Plate Elements - Six Degree of Freedom Entries per Point: Corresponding Displacements (u, v, w, θ_x, θ_y, θ_z).

(3) Toroidal Thin Shell Ring Element - Nine Degree of Freedom Entries per Point: Corresponding Displacements (u, o, w, o, θ_y, o, u', o, w'').

Following the MODAL entry are the entries pertaining to Listed Input. Included are Grid Point Numbers, Repeat Option and corresponding boundary conditions as follows:

Grid Point Number - (Cols. 7-11)

(1) Grid points are entered as fixed point numbers.

(2) Grid points can be entered in any order.

Repeat - (Col. 12)

The repeat option allows the User to repeat reoccurring boundary conditions, from grid point to grid point. This is accomplished in the following manner. If the boundary conditions at a number of grid points are identical, the User enters the grid point number and associated boundary conditions for the first grid point. For the following points with identical boundary conditions, just the grid point number (Cols. 7-11) and an 'X' in the Repeat (Col. 12) need be entered.

REMEMBER:

(1) The repeat option can be used effectively for sets of grid points which have identical boundary conditions.

(2) The Number of Input Boundary Condition Points must be specified on the System Control Information Data Form (Figure II-3). This value is equal to the number of exceptions to the MODAL card.

12. Prescribed Displacement Section (Figure II-11)

Applied loading may be prescribed in terms of non-zero displacement values. The number of prescribed displaced grid points is the number of grid points that are assigned known values of displacement other than zero.

This section is used in conjunction with the Boundary Condition Section when an input code '2' is used in that section in a STATICS Analysis. This code designates that the grid point degree of freedom for which '2' is entered has a prescribed displacement. In order to input the actual value for each prescribed displacement, the Prescribed Displacement Data Form is provided and is shown in Figure II-11.

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE - 0 - No Displacement Allowed
1 - Unknown Displacement
2 - Known Displacement

1	2	3	4	5	6	
B	O	U	N	D		(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	Θx	Θy	Θz	1	2	3	
13	14	15	16	17	18	19	20	21	
									(/)

LISTED INPUT

Grid Point Number					Repeat										
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
															(/)
															(/)
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FIGURE II-10 BOUNDARY CONDITION DATA FORM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS
(continued)

INPUT CODE 0 - No Displacement Allowed
1 - Unknown Displacement
2 - Known Displacement

LISTED INPUT

Grid Point Number					Repeat	TRANSLATIONS			ROTATIONS			GENERALIZED			
						U	V	W	θx	θy	θz	1	2	3	
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
															(/)
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FIGURE II-10 CONCLUDED

A total of nine possible prescribed displacements per grid point are provided for in the section. These are as follows:

(1) three Translations (u, v, w)

(2) three Rotations (θ_x, θ_y, θ_z) and

(3) three Generalized Displacements (1, 2, 3).

The total number of degree of freedom entries per grid point is a function of the element type being employed in the analysis.

(1) Triangular Cross-Section Ring, Trapezoidal Cross-Section Ring (Core) - Three Degree-of-Freedom Entries per Point: Possible Displacements (u,v,w).

(2) Frame Element, Incremental Frame Element, Quadrilateral Shear Panel, Quadrilateral and Triangular Thin Shell Elements, Quadrilateral and Triangular Plate Elements - Six Degree-of-Freedom Entries per Point: Corresponding Displacements (u, v, w, θ_x, θ_y, θ_z).

(3) Toroidal Thin Shell Ring Element - Nine Degree of Freedom Entries per Point: Possible Displacements (u, o, w, o, θ_y, o, u', o, w'').

Where the (u', o, w'') correspond to the last three generalized displacements (1, 2, 3) which will be completely described in the Toroidal Ring portion of the Element Control Section.

The applicable values of prescribed displacement are entered as floating point numbers. It is important to note that Keypunch Personnel have been instructed to ignore entries that are not filled in. Blank entries are not considered as zero's. Zero's must be entered in an entry when applicable.

The first entry on the Prescribed Displacement Data Form is prelabeled PRDISP and requires no information from the User. The second entry is prelabeled PCOND in columns 1-5. Columns 7-11 are reserved for the Condition Number.

Condition Number - (Cols. 7-11)

The condition number is a fixed point number. In the present MAGIC System either 1 or NL displacement load condition can be accommodated per execution. NL is defined as the total number of loading conditions in a given analysis.

The next entry on the form is the MODAL entry. This entry allows the User to input a set of prescribed displacements which the program assumes to apply to every grid point unless otherwise indicated by a separate grid point entry on the grid point cards. MODAL is prelabeled on this card and the only information required by the User are the prescribed displacement values which have been discussed previously.

The third and following entries contain information pertaining to the Grid Point Numbers, Repeat Option and prescribed displacement values as follows:

Grid Point Number - (Cols. 7-11)

(1) Grid Points are entered as fixed point numbers.

(2) Grid Points can be entered in any sequence desired.

Repeat - (Col. 12)

The repeat option allows the User to repeat values of prescribed displacements from grid point to grid point. This is accomplished in the following manner. If the prescribed displacements at a number of grid points are identical, the User enters the grid point number and associated displacements for the first grid point. For the following points with identical displacements, the only grid point number (Col. 7-11) and an 'X' in the Repeat (Col. 12) need be entered. No additional cards are needed for repeated grid points.

REMEMBER:

(1) Zeros must be entered when applicable. Blanks are not zeros.

(2) If the number of degree of freedom entries per grid point is equal to three (3), then only the translation entry (u, v, w) is applicable. The other two entries (Rotations and Generalized) are ignored by the User.

(3) If the number of degree of freedom entries per grid point is equal to six (6) then the translation and rotation entries must be considered. If for instance, at a certain grid point there are prescribed values of translations, but not rotations, zeros must be entered for the rotation values or the rotation entry will be ignored by the Keypunch Operator. This would cause premature termination of the run since six degree of freedom elements require two cards per grid point, except for repeated grid points.

(4) If the number of degree of freedom entries per grid point is equal to nine (9) - (Toroidal Ring Element) then entries for translation, rotation and generalized values of displacement must be entered where applicable. If some of these entries are equal to zero, these zero values must still be entered otherwise the entries will be ignored by the Keypunch Operator causing termination of the run.

(5) The Number of Prescribed Displaced Grid Points must be specified on the System Control Information Data Form (Figure II-3). This value is equal to the number of exceptions to the MODAL card.

SUMMARY:

For convenience the last three Reminders are briefly stated as,

(1) Three (3) Degree of Freedom Entries per Grid Point; 1 Prescribed Displacement Card Required per Grid Point.

(2) Six (6) Degree of Freedom Entries per Grid Point; 2 Prescribed Displacement Cards Required per Grid Point.

(3) Nine (9) Degree of Freedom Entries per Grid Point; 3 Prescribed Displacement Cards Required per Grid Point.

(4) Repeated grid points require only one card.

13. External Grid Point Load's Section - (Figure II-12)

Concentrated loads are specified by component against grid point number. For convenience the axes of reference may be specified optionally as Global or Local System (grid point) Axes.

The labeled input data format provided for the External Grid Point Loads Section is shown in Figure II-12. A total of nine possible external loads are provided for in this section. These are as follows:

(1) three Forces (F_x, F_y, F_z),

(2) three Moments (M_x, M_y, M_z) and

(3) three Generalized Forces (F_1, F_2, F_3).

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MAGIC STRUCTUR
INPUT D

1	2	3	4	5	6
P	R	D	I	S	P

(/)

1	2	3	4	5	6	7	8	9	10	11
P	C	C	N	D						

(/)

Condition Number

PRESCRIBE

TRANSLATIONS

U | V | W

R

θ_x

1	2	3	4	5	6
M	O	D	A	L	

(/)

Grid Pt. Number

repeat

(/)

FIGURE II-11 PRESCRIBED DISPLACEMENT DATA FORM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

PRESCRIBED DISPLACEMENTS

ROTATIONS				GENERALIZED		
θ_x	θ_y	θ_z		1	2	3
1 3 4 5 6 7 8 9 0 1 2	2 3 4 5 6 7 8 9 0 1 2	3 3 4 5 6 7 8 9 0 1 2 4	(/)	1 3 4 5 6 7 8 9 0 1 2	2 3 4 5 6 7 8 9 0 1 2	3 3 4 5 6 7 8 9 0 1 2 4

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Element Applied Load Scalar - (Cols. 13-22)

The Element Applied Load Scalar (EALS), entered as a floating point number, is a device which enables the User to scale the element applied load up or down by a scalar multiplier. Element applied loading is pressure or thermal loading. The EALS is utilized in the following way.

Total Load = External Grid Point Loads + (EALS)
x Element Applied Loads

For multiple load conditions, the EALS is always applied to the original element applied loads. As an example, if for the first loading condition, the EALS = 0.50, the Total Load would equal the following:

Total Load = External Grid Point Loads + (0.5)
x Element Applied Loads

If for the second load condition, the EALS = 0.10, the Total Load would equal the following:

Total Load = External Grid Point Loads + (0.1)
x Original Element Applied Loads

External Loads Transformation - (Col. 24)

For User convenience an option has been provided to allow external loads to be input by specifying the axes of reference as either Global or Local System (grid point) Axes.

If Graxes are not employed in an analysis the loads are assumed to be in the Global System and Column 24 is left blank.

If GRAXES are employed (See Sections 9 and 10, Figures II-8 and II-9) the following applies:

(a) If a '1' is entered in Column 24, the loads will not be transformed, which indicates that the loads have been entered with reference to the gridpoint axes system.

(b) If Column 24 is left blank the loads will be transformed utilizing the grid point axes transformation. This indicates that the program assumes that the loads are entered with respect to the Global System of reference.

The next entry on the form is the MODAL entry. This entry allows the User to input a set of External Loads which the program assumes to apply to every grid point unless otherwise indicated by

The total number of degree of freedom entries per grid point is dependent on the element type being employed in the analysis. Three types appear in the MAGIC System, i.e.

(1) Triangular Cross-Section Ring, Trapezoidal Cross-Section Ring (Core) - Three Degree-of-freedom entries per point: Possible External Forces (F_x, F_y, F_z).

(2) Frame Element, Incremental Frame Quadrilateral Shear Panel, Quadrilateral and Triangular Thin Shell Elements, Quadrilateral and Triangular Plate Elements Six Degree-of-freedom entries per point: Possible external forces (F_x, F_y, F_z, M_x, M_y, M_z).

(3) Toroidal Thin Shell Ring - Nine Degree of Freedom Entries per Point: Possible External Forces (F_x, 0, F_z, 0, M_y, 0, F_1, 0, F_3). The F_1, 0 and F_3 are a set of generalized forces which will be described in detail in the section dealing with the Toroidal Ring Element.

The applicable concentrated Grid Point Loads are entered as floating point numbers. It is important to note that Keypunch Personnel have been instructed to ignore entries that are <u>not</u> filled in. Blank entries are <u>not</u> considered as zeros. Zeros <u>must</u> be entered in an entry when applicable.

The first entry on the External Grid Point Loads Form is prelabeled LOADS and requires no information from the User. The second entry is prelabeled LCOND in Columns 1-5. The User supplies two items of information for this entry as follows:

<u>Condition Number - (Cols. 7-11)</u>

(1) Each external load condition requires a number.

(2) Each External Load Condition is entered on a Separate labeled input data form.

(3) In every analysis, the User must designate at least one (1) External Load Condition. This applies even when there are no External Loads acting on the system.

(4) The condition number is entered as a fixed point number.

Element Applied Load Scalar - (Cols. 13-22)

The Element Applied Load Scalar (EALS), entered as a floating point number, is a device which enables the User to scale the element applied load up or down by a scalar multiplier. Element applied loading is pressure or thermal loading. The EALS is utilized in the following way.

Total Load = External Grid Point Loads + (EALS) x Element Applied Loads

For multiple load conditions, the EALS is always applied to the original element applied loads. As an example, if for the first loading condition, the EALS = 0.50, the Total Load would equal the following:

Total Load = External Grid Point Loads + (0.5) x Element Applied Loads

If for the second load condition, the EALS = 0.10, the Total Load would equal the following:

Total Load = External Grid Point Loads + (0 1) x Original Element Applied Loads

External Loads Transformation - (Col. 24)

For User convenience an option has been provided to allow external loads to be input by specifying the axes of reference as either Global or Local System (grid point) Axes.

If Graxes are not employed in an analysis the loads are assumed to be in the Global System and Column 24 is left blank.

If GRAXES are employed (See Sections 9 and 10, Figures II-8 and II-9) the following applies:

(a) If a '1' is entered in Column 24, the loads will not be transformed, which indicates that the loads have been entered with reference to the gridpoint axes system.

(b) If Column 24 is left blank the loads will be transformed utilizing the grid point axes transformation. This indicates that the program assumes that the loads are entered with respect to the Global System of reference.

The next entry on the form is the MODAL entry. This entry allows the User to input a set of External Loads which the program assumes to apply to every grid point unless otherwise indicated by

a separate grid point entry on the grid point cards. MODAL is prelabeled on this card and the only information required by the User are the External Load Values which have been discussed previously.

The third and following entries contain information pertaining to the Grid Point Numbers, Repeat Option and External Loads, as follows:

Grid Point Number - (Cols. 7-11)

(1) Grid Point Numbers are entered as fixed point numbers.

(2) Grid Point Numbers can be entered in any sequence desired.

Repeat - (Col. 12)

The repeat option allows the User to repeat values of external loads from grid point to grid point. This is accomplished in the following manner. If the external loads at a number of grid points are identical, the User enters the grid point number and associated external loads for the first grid point. For the following points having identical loads, only the grid point number (Col. 7-11) and an 'X' in the Repeat (Col. 12) need be entered.

REMEMBER:

(1) The External Grid Point Loads Section must be utilized even if there are no external grid point loads acting on the structure. For this case only the MODAL Card is required with zero entries in the appropriate locations.

(2) The Repeat option can be used effectively for sets of grid points having identical external loads.

(3) External Grid Point Loads are not element related and should not be confused with element applied loads such as pressures and thermal loading.

(4) The number of external load conditions must be specified on the System Control Information Data Form (Figure II-3).

(5) Zeros must be entered when applicable Blanks are not zeros.

(6) If the number of degree of freedom entries per grid point is equal to three (3) then only the force values (F_x, F_y, F_z) are applicable. The other two entries (Moments and Generalized Forces) are ignored by the User.

(7) If the number of degree of freedom entries per grid point is equal to six (6) then the Force and Moment Values must be considered. If for instance, at a certain grid point there are applied forces but no applied moments, zeros must be entered for the Moment values or this entry will be ignored by the Keypunch Operator. This would cause premature termination of the run since six degree of freedom elements require two External Load cards per grid point.

(8) If the number of degree of freedom entries per grid point is equal to nine (9) then Forces, Moments and Generalized Forces must be entered. If some of these entries are equal to zero, these zero values must still be entered otherwise the entries will be ignored by the Keypunch Operator causing premature termination of the run.

(9) Repeated grid points require only one card.

SUMMARY:

For convenience the last four Reminders are briefly stated as,

(1) Three (3) Degree of Freedom Entries per Grid Point; 1 External Load Card Required per Grid Point.

(2) Six (6) Degree of Freedom Entries per Grid Point; 2 External Load Cards Required per Grid Point.

(3) Nine (9) Degree of Freedom Entries per Grid Point; 3 External Load Cards Required per Grid Point.

(4) Repeated grid points require only one card.

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MAGIC STRUCTURAL ANALY
INPUT DATA FORM

1	2	3	4	5	6
L	O	A	D	S	

(/)

Transformation Code For Loads

1	2	3	4	5	6
L	C	O	N	D	

(/)

Condition Number

Scalar

EXTERNAL

FORCE VALUES — F_x, F_y, F_z

MOMENT — M_x, M_y

1	2	3	4	5	6
M	O	D	A	L	

Grid Pt. Number

Repeat

FIGURE II-12 EXTERNAL GRID POINT LOADS DATA FORM

rmation
r Loads

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERNAL LOADS

ES		MOMENT VALUES				GENERALIZED VALUES			
Fz		Mx	My	Mz		1	2	3	
4		1 2	2 3	3 4		1 2	2 3	3 4	
6 7 8 9 0 1 2		3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2		3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	
	(/)				(/)				(/)

4		1 2	2 3	3 4		1 2	2 3	3 4	
6 7 8 9 0 1 2		3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2		3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	3 4 5 6 7 8 9 0 1 2	
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14. <u>Element Control Data Section (Figure II-13)</u>

The Element Control Data Section establishes control on the types and number of elements which are to be used in a specific analysis. A prelabeled input data form is provided for the Element Control Data Section and is shown in Figure II-13. This form is applicable to all finite elements which are contained in the MAGIC library. Upon examination of the form it is seen that certain data are applicable to all of the elements in the library while other data are element dependent.

The first entry on the form is prelabeled ELEM and requires no information from the User. The second and following entries contain the following information.

<u>Element Number - (Cols. 7-10)</u>

(1) The element number which defines the element being considered is entered in this location.

(2) Elements can be entered in any sequence desired.

(3) The element number is entered as a fixed point number.

<u>Plug Number - (Cols. 11-12)</u>

(1) Each finite element in the Element Library has an identification number as follows:

(a) Number 11 - Frame Element

(b) Number 13 - Incremental Frame Element

(c) Number 25 - Quadrilateral Shear Panel

(d) Number 40 - Triangular Cross-Section Ring

(e) Number 41 - Trapezoidal Cross-Section Ring (Core)

(f) Number 21 - Quadrilateral Thin Shell

(g) Number 20 - Triangular Thin Shell

(h) Number 28 - Quadrilateral Plate

(i) Number 27 - Triangular Plate

(j) Number 30 - Toroidal Ring

(2) Identification Numbers are entered as fixed point numbers.

<u>Material Number - (Cols. 13-18)</u>

The material number is the number of the material associated with the element in question. This number is referenced to the material tape. For instance, if the

User were using material number 138, this material would have had to be on the tape at the time of the run or be a material that the User was adding to the tape for this particular run. The material number must appear exactly as it was in Cols. 10-15 of the MATER section.

Temperature Interpolate Option - (Col. 19)

The Temperature Interpolate Option is exercised in the following manner:

(1) If an entry is not made in Column 19, the program will average the node point temperatures of the element in question and use this average temperature when establishing material properties from the material tape.

(2) If a '1' is entered in Column 19, the program will use the Material Temperature entered in Columns 20-27 when establishing material properties from the material tape.

(3) If a number n $(n > 1)$ is entered in Column 19, then this number is equal to the number of node points which will participate in the averaging process. The first n node points entered in Columns 36-71 (Node Point Section), of the Element Control Data Section will then be used in the averaging process.

Material Temperature - (Cols. 20-27)

If the User exercises the Temperature Interpolate Option by placing a '1' in Column 19, then a temperature associated with the element in question should be entered in Columns 20-27 in a thermal stress analysis. The program will then use this temperature when establishing material properties from the Material Tape.

Repeat Element Matrices - (Col. 28)

Element matrices generated for assembly against a particular finite element specification can also be used for the next element in the calculation sequence. This avoids repeated calculation of identical element matrices. Experience indicates a high frequency of opportunities for exploiting this feature. Input data requirements and execution times can be significantly reduced with use of this feature. The option is exercised by the User by placing an 'X' in Col. 28 opposite the Element Number for which element matrices are to be repeated.

Element Input - (Col. 29)

Certain of the elements contained in the MAGIC System element library require Element Input peculiar to that element. All of the elements available in the MAGIC element library require Element Input with the exception of the Triangular and Trapezoidal Cross-Section Ring Elements where it depends upon the type of analysis being performed. For elements which require Element Input, an 'X' is placed in Column 29.

A prelabeled input data form is provided especially for Element Input. This form will be discussed in detail immediately following the discussion of the Element Control Data input form.

Interpolated Input Print - (Col. 30)

If the User places an 'X' in Column 30, the following information is obtained:

(1) Material Number

(2) Material Identification

(3) Type of Material, i.e. Isotropic or Orthotropic

(4) Interpolated Material Properties, which include

- (a) Temperature
- (b) Young's Modulus
- (c) Poisson's Ratio
- (d) Thermal Expansion Coefficients
- (e) Rigidity Moduli

Element Matrix Print - (Col. 31)

If the User places an 'X' in Column 31, a print of element matrices associated with the element in question is obtained.

Full Print (Col. 32)

If the User places an 'X' in Column 32 a total print of all element matrices and intermediate computations is obtained for the element in question. In general, this option is exercised when debugging a problem

Number of Input Nodes - (Cols. 33-34)

The number of input nodes is the number of node points which define an element. The following number of node points are applicable to the elements in the MAGIC Library.

(1) Frame Element:	3 Node Points
(2) Incremental Frame Element:	3 Node Points
(3) Quadrilateral Shear Panel:	4 Node Points
(4) Triangular Cross-Section Ring:	3 Node Points
(5) Trapezoidal Cross-Section Ring (Core):	4 Node Points
(6) Quadrilateral Thin Shell:	8 Node Points
(7) Triangular Thin Shell:	6 Node Points
(8) Quadrilateral Plate:	4 Node Points
(9) Triangular Plate:	3 Node Points
(10) Toroidal Ring:	2 Node Points

Pressure Suppression Option - (Col. 35)

Pressure Load Matrices are generated at the element level in the MAGIC System. The User has the option of placing an 'X' in Column 35, if it is desired to suppress the generation of the pressure Load Vector for any particular element.

Node Points - (Cols. 36-71)

These locations are reserved for the node points which describe the element in question. The User should note that three column fields are set aside for each node point. There are 12 locations set aside for node points. The last four locations (9, 10, 11, and 12) apply only to the quadrilateral and triangular thin shell elements. Their use will be fully described in the section which pertains to the quadrilateral and triangular thin shell elements.

REMEMBER:

The total Number of Elements must be called out on the System Control Information Data Form (Figure II-3).

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ELEM					
1	2	3	4	5	6

(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER	PLUS NO.	MATERIAL NUMBER	Interpolate Option	MATERIAL TEMPERATURE	Repeat Elem. Matrices	Elem. Input	PRINT: Print	PRINT: Elem. Mat.	PRINT: Full	Number of Input Nodes	Suppress Pressures	NODE POINTS 1	2	3	4	5	6	7	8	9	10	11	12
7 8 9 10	1 2	3 4 5 6 7 8	19	20 1 2 3 4 5 6 7	28	29	30	31	32	33 34	35	36 7 8	9 40 1	2 3 4	5 6 7	8 9 50	1 2 3	4 5 6	7 8 9	60 1 2	3 4 5	6 7 8	9 70 1

FIGURE II-13 ELEMENT CONTROL DATA FORM

15. Element Input Section - (Figure II-14)

A labeled input data form is provided for the Element Input Section. This form is used for elements which require Element Input: (Column 29 of the Element Control Data Section).

The first entry on the form is prelabeled EXTERN and requires no information from the User. The second entry on the input data form is the MODAL entry which allows the User to input element input which the program assumes to apply to every element unless otherwise indicated in the Element Number entries which follow the MODAL card. It can be seen from the input data form that the Element Input is labeled A, B, C, D, E, F with each item contained in a ten column field. These are the locations where the element input is entered, if the element being used requires element input. The entries made in locations A through F are entered as floating point numbers. The values which are entered in these locations are functions of the type of element being employed in the analysis. This input, therefore, is element related and will be explained in detail for each element in the following sections.

The third and following entries in the section contain information pertaining to the Element Numbers, Repeat Option and Element Input, i.e.:

Element Number - (Cols. 7-11)

(1) Element numbers are entered as fixed point numbers.

(2) Element numbers must be entered consistent with the order in which they were entered in the Element Control Data Section.

Repeat - (Col. 12)

The repeat option provides the User with the opportunity to repeat Element Input from element to element. This is accomplished in the following manner. If the element input for a number of elements is identical, the User enters the element number and associated element input for the first element. For the following elements having the same element input, only the Element Number (Col. 7-11) and an 'X' in the Repeat column need be entered.

REMEMBER:

(1) For a problem with identical Element Input for every element only the MODAL entry is required.

(2) The repeat option can be used effectively for sets of elements that have the same Element Input.

(3) The type of element input required for an element is a function of element type. This element input will be completely described in the following sections.

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MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

E	X	T	E	R	N	(/)
1	2	3	4	5	6	

ELEMENT INPUT

1	2	3	4	5	6
M	O	D	A	L	

	A	B	C	D	E	F
	13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42	43 44 45 46 47 48 49 50 51 52	53 54 55 56 57 58 59 60 61 62	63 64 65 66 67 68 69 70 71 72

Element Number	Repeat							
7 8 9 10 11	12	13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42	43 44 45 46 47 48 49 50 51 52	53 54 55 56 57 58 59 60 61 62	63 64 65 66 67 68 69 70 71 72	
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FIGURE II-14 ELEMENT INPUT DATA FORM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT INPUT
(continued)

Element Number	Repeat	A	B	C	D	E	F	
7 8 9 10 1	2	13 4 5 6 7 8 9 20 1 2	23 4 5 6 7 8 9 30 1 2	33 4 5 6 7 8 9 40 1 2	43 4 5 6 7 8 9 50 1 2	53 4 5 6 7 8 9 60 1 2	63 4 5 6 7 8 9 70 1 2	
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FIGURE II-14 CONCLUDED

10. Element Input Description

a. Frame Element (Ident. No. 11)

The frame discrete element is suitable for idealization of all structures which are adequately characterized by "beam theory". The frame element representation is developed in detail in Reference 8, and is shown in Figure II-15.

Geometric specification of the straight slender prismatic frame element is given, in part, by the end point coordinates. A third coordinate point in the element X_g-Y_g positive quadrant is required to specify twist orientation.

The cross-section of the frame element is assumed doubly symmetric with respect to element geometric axes. It is characterized by moments of inertia about the three element axes together with the cross-sectional area.

A linear Hooke's Law is assumed to govern material behavior. Temperature referenced mechanical and physical material properties are selected from the material library.

The frame element representation includes membrane, torsion, and flexure actions. These contributions are uncoupled in consequence of the zero curvature and cross-section symmetry assumptions.

Deformation behavior of the basic frame element is described by the twelve displacement degrees of freedom associated with the two grid points which it connects. Description of stress behavior is accepted as the definition of the twelve forces acting at the two grid point connections.

The following element matrices are provided for the Frame Element in the MAGIC System.

Stiffness

Stress

Distributed Loading

Axial Thermal Load

Incremental Stiffness

Consistent Mass

Referring to Figure II-15, it is seen that the Frame Element is defined by three node points and that the third point determines the X_g-Y_g plane of the element. This fact is important if distributed loading is present in an analysis. The frame element is provided with a linearly varying pressure load. Provision is made for loading in both the element Y_g and Z_g directions. The Grid Point Pressure Data Form (Figure II-6) is provided for these pressure loadings if they exist. On that form provision is made for three possible input pressures per grid point, P_1, P_2, and P_3.

For the Frame Element, pressure (distributed Loading) values acting in the element Y_g direction correspond to pressures designated, P_1 on the Grid Point Pressure Data Form. These pressure values are input in Columns 13-22. Pressures acting in the element Z_g direction correspond to pressure designated, P_2 on the Grid Point Pressure Data Form. These pressures are input in columns 23-32. Pressures are defined as positive if acting in the direction of positive element Y_g or Z_g directions.

An axial thermal load vector is also provided for the Frame Element. It is based on the assumption of a uniform temperature over the length of the element. The latter being the average of the two grid point temperatures. The Grid Point Temperature Data Form (Figure II-7) is provided for these temperature values if they exist. In that section provision is made for three possible input temperatures, T_1, T_2, and T_3.

For the Frame Element, the node point temperatures correspond to the temperature designated T_1 on the Grid Point Temperature Data Form. These temperature values are input in Columns 13-22 of that form.

The Element Control Data which is required for the Frame Element is as follows. (See Figure II-13)

<u>Element Number - (Cols. 7-10)</u>

Refer to Element Control Section.

<u>Plug Number - (Cols. 11-12)</u>

The Frame Element is identified as Number 11.

Material Number - (Cols. 13-18)

Refer to Element Control Section

Temperature Interpolate Option-(Col. 19)

If the User exercises this option, the program will average the node point temperatures of the element, and use this temperature when establishing material properties from the material tape. The Frame Element is defined by three node points as explained previously with the third node point establishing the twist orientation of the element. Because of this only the first two node points will participate in the temperature averaging process in general. Therefore a '2' is usually entered for the Frame Element in this column when the Interpolate Option is being exercised.

Material Temperature - (Cols. 20-27)

Refer to Element Control Section.

Repeat Element Matrices - (Col. 28)

Refer to Element Control Section.

Element Input - (Col. 29)

The Frame Element always requires Element Input therefore an 'X' is always placed in Column 29 when a Frame Element is being employed.

The following element input is required when using the Frame Element. (Refer to the Element Input Section and the Sample Element Input Data Form, Figure II-14). From the form, it is seen that the Element Input Locations are labeled A, B, C, D, E, F with each item contained in a ten column field.

The Element Input for the Frame Element consists of the following information.

Location A - (Cols. 13-22)

Cross-Section Area, (A)

Location B - (Cols. 23-32)

Area Moment of Inertia, I_{zz} which is defined in the following manner: (See Figure II-15)

$$I_{zz} = \int_A Y^2 \, dA$$

Location C - (Cols. 33-42)

Area moment of inertia, I_{yy} which is defined in the following manner: (See Figure II-15)

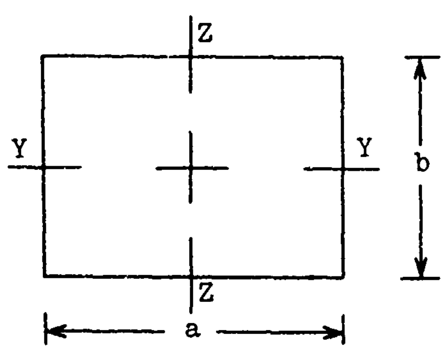
$$I_{yy} = \int_A Z^2 \, dA$$

Location D - (Cols. 43-52)

Torsional Moment of Inertia, J, which for a circular cross-section is equal to:

$$J = I_{zz} + I_{yy}$$

and for a rectangular cross-section.



For a>b

can be approximated by:

$$J = ab^3 \left(1/3 - 0.21 \, b/a \left[1 - (1/12)(b^4/a^4) \right] \right)$$

For a > b

Location E - (Cols. 53-62)

Eccentricity, ECC - An eccentric connection of a finite element to adjacent elements is effected by a special type of matrix transformation. Eccentricity of an element is specified through the element data and measured with respect to the element geometric axis.

The eccentricity is defined as the distance from the neutral axis of the eccentrically placed frame element to the connection line. The eccentricity is taken to be positive when the direction specified from the eccentric element to the connection line is in the positive local Y direction. (Figure II-15)

It should be noted by the User that if Eccentric Connections are not pertinent in an analysis then this entry is ignored by the User. It should also be noted that the Frame Element degenerates into an Axial Force Member if the only entry made in the Element Input Section is Location A. (Cross-Section Area).

Returning to the Element Control Data Section, the list of data items continues as follows;

Interpolated Input Print - (Col. 30)

Element Matrix Print - (Col. 31)

Full Print - (Col. 32)

Refer to Element Control Section

Number of Input Nodes - (Col. 33-34)

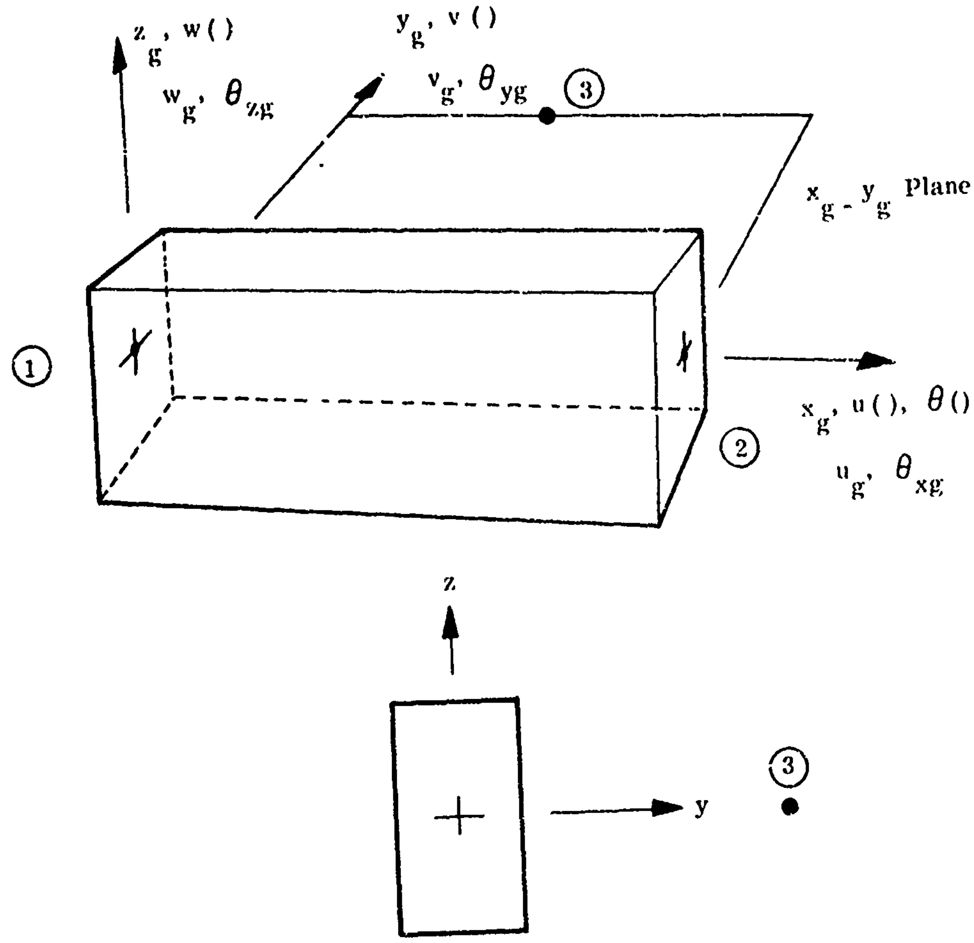
The Frame Element is always defined by 3 input nodes.

Pressure Suppression Option (Col. 35)

Refer to Element Control Section.

Node Points - (Col. 36-71)

The three node points which define each Frame Element are entered in these locations.



Cross Section

Figure II-15 Frame Element Representation

b. Quadrilateral Shear Panel (Ident. No. 25)

The quadrilateral shear panel is appropriate for representation of thin membranes. In order to transmit direct forces it must be used in combination with a truss specialization of the frame element. The shear panel element representation is developed in detail in Reference 9, and is shown in Figure II-16. The general quadrilateral shape of the shear panel is defined by the coordinates of the four corner points. Geometric definition is completed by specification of an effective uniform thickness.

A pure shear stress state is assumed. Stiffness coefficients are generated for corner point displacements under this pure shear assumption.

A deformation behavior of the shear panel discrete element is described by the eight corner point displacement degrees of freedom associated with the four grid points which it connects. Description of stress behavior is accepted as the constant shear stress value.

The following element matrices are provided for the quadrilateral shear panel in the MAGIC System.

Stiffness

Stress

The Element Control Data which is required for the Quadrilateral Shear Panel is as follows. (See Figure II-13)

Element Number - (Cols. 7-10)

Refer to Element Control Section

Plug Number - (Cols. 11-12)

The Quadrilateral Shear Panel is identified as Number 25.

Material Number - (Cols. 13-18)

Refer to Element Control Section

Temperature Interpolate Option - (Col. 19)

The Quadrilateral Shear Panel is designated by 4 node points. If the User desires to exercise the Temperature Interpolate Option, and average all four (4) of the node point temperatures, an entry is not made in Column 19. If the User only wants to use the first n node points in the averaging process ($n<4$) then this number, n, is entered and the program will take the first n node points entered in Columns 36-71 and use these in the averaging process, when determining material properties. If the User desires to enter a Material Temperature in Columns 20-27 then a '1' is entered in Column 19 which tells the program to use this Material Temperature when establishing material properties from the tape.

Material Temperature - (Cols. 20-27)

Repeat Element Matrices - (Col. 28)

Refer to Element Control Section

Element Input - (Col. 29)

The Quadrilateral Shear Panel always requires Element Input. Therefore, an 'X' is always placed in Column 29 when a Quadrilateral Shear Panel is being employed.

The Element Input (Figure II-14) required for the Quadrilateral Shear Panel consists of the following information:

Location A - (Cols. 13-22)

Thickness, (t)

The above is the only Element Input which is required for the Shear Panel.

Returning to the Element Control Data Section, the list of data items continues as follows:

Interpolated Input Print - (Col. 30)

Refer to Element Control Section

Element Matrix Print - (Col. 31)

Full Print - (Col. 32)

Refer to Element Control Section

Number of Input Nodes (Cols. 33-34)

The Quadrilateral Shear Panel is always defined by 4 input nodes.

Pressure Suppression Option (Col. 35)

Refer to Element Control Section.

Node Points - (Cols. 36-71)

The four node points which define each quadrilateral Shear Panel are entered in the first four entries provided in the Node Point Section of the Element Control Data Form.

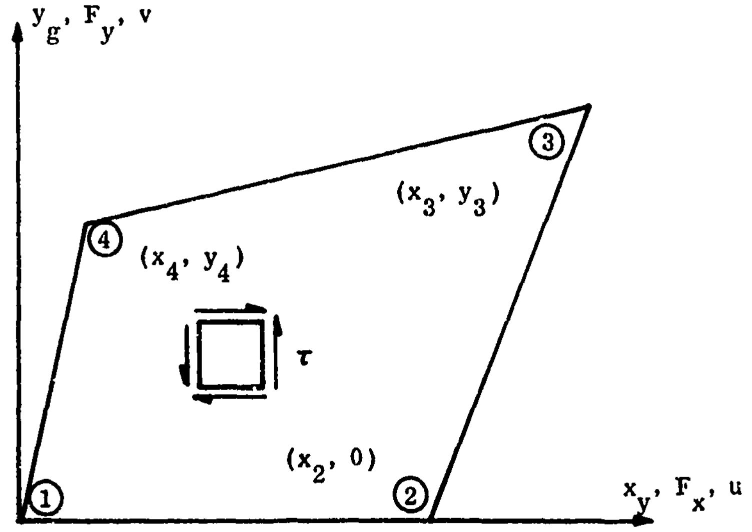


Figure II-16 Quadrilateral Shear Panel Representation

c. Triangular Cross Section Ring (Ident. No. 40)

The triangular cross-section ring discrete element, shown in Figure II-17, is suitable for idealization of axisymmetric thick walled structures of arbitrary profile. A detailed development of the element representation is presented in Reference 10.

The ring element representation is written with respect to cylindrical coordinate axes. The configuration of the element is completely defined by specifying radial and axial coordinates of the corner points.

Cylindrical anisotropy is provided for in the mechanical and physical material properties of the ring element. Orientation of orthotropic axes in the (r, z) plane is data specified.

The element designation "ring" implies an axisymmetric geometric configuration. It has been further tacitly assumed that the applied loading is axisymmetric; it follows, as a consequence, that the displacement behavior is also.

A three dimensional axisymmetric stress state is assumed. Linear Polynomial functions are employed for displacement mode shapes leading to constant element strain and stress states.

Element field loads are assumed constant over the cross-section. A linearly varying boundary pressure is included.

Deformation behavior of the ring element is described by the six displacement degrees of freedom associated with the three grid points which it connects. The predicted element stress behavior is constant over the triangular cross-section. Radial, circumferential, and axial stresses are predicted.

The Triangular Ring is numbered in the following manner. Referring to Figure II-17, the element is numbered in a counter-clockwise manner when looking in the positive element Y (θ) direction.

The following element matrices are provided for the Triangular Cross-Section Ring in the MAGIC System.

Stiffness
Stress
Thermal Load
Distributed Loading (Pressure)
Consistent Mass

The Triangular Cross-Section Ring Element is provided with a linearly varying pressure load. The pressure is defined as positive when acting <u>into</u> the element (Figure II-17). Provision is made for pressure loading on only <u>one</u> side of the element. This side of the element is always defined by the first two node point numbers which are called out in the Node Point locations of the Element Input Section.

The Grid Point Pressure Data Form (Figure II-6) is provided for entering these pressure loadings if they exist. For the Triangular Ring Element, the input pressures correspond to pressures designated, P_1 on the Grid Point Pressure Data Form. These pressure values are input in Columns 13-22 of that Form.

A constant prestrain load vector is included in this element representation to accommodate thermal loading. The Grid Point Temperature Data Form (Figure II-7) is provided to input node point temperatures if thermal loading is present. For the Triangular Ring Element, the node point temperatures correspond to the temperature designated T_1 on the Grid Point Temperature Data Form. These temperature values are input in Columns 13-22 of that Form.

The Element Control Data which is required for the Triangular Ring Element is as follows: (See Figure II-13).

<u>Element Number - (Cols. 7-10)</u>

Refer to Element Control Section

<u>Plug Number - (Cols. 11-12)</u>

The Triangular Cross-Section Ring Element is identified as Number 40.

<u>Material Number - (Cols. 13-18)</u>

Refer to Element Control Section

<u>Temperature Interpolate Option - (Col. 19)</u>

The Triangular Ring Element is designated by 3 node points. If the User desires to exercise the Temperature Interpolate Option and average all three (3) of the node point temperatures, an entry is <u>not</u> made in Column 19. If the User desires to enter a material temperature in Cols. 20-27, a '1' is entered in Column 19.

Material Temperature - (Cols. 20-27)

Refer to Element Control Section

Repeat Element Matrices - (Col. 28)

Refer to Element Control Section

Element Input - (Col. 29)

The Triangular Cross-Section Ring Element only requires Element Input under certain special conditions as follows: Referring to Figure II-17, it is seen that there is a possibility that in some cases the material axis, and element geometric axis of the element will not coincide. If this is the case the Element Input (Figure II-14) required for the Triangular Cross-Section Ring consists of the following.

Location A - (Cols. 13-22)

Material Axes Angle (Gamma - γ_{mg})

Since the Triangular Cross-Section Ring Element is written to accommodate anisotropy of mechanical and physical properties, provision is made in the program for differences in orientation of material and element geometric axes for an element. The User inputs the angle between the element material axis (X_m) and the element geometric axis (X_g). The angle gamma (γ_{mg}) is input in degrees and is considered positive when measured from the material axes to the element geometric axes, in a counter-clockwise direction (Figure II-17).

Remember

Element Input is not required for the Triangular Ring if the material and geometric axes coincide, i.e., $\gamma_{mg} = 0$.

Returning to the Element Control Data Section, the list of data items continues as follows:

Interpolated Input Print - (Col. 30)
Element Matrix Print - (Col. 31)
Full Print (Col. 32)

$\left.\begin{array}{l}\\ \\ \\ \end{array}\right\}$ Refer to Element Control Section

Number of Input Nodes (Cols. 33-34)

The Triangular Cross-Section Ring Element is always defined by 3 input nodes.

Pressure Suppression Option (Col. 35)

Refer to Element Control Section.

Node Points - (Cols. 36-71)

The three node points which define each Triangular Ring are entered in the first three entries provided in the Node Point Section of the Element Control Data Form.

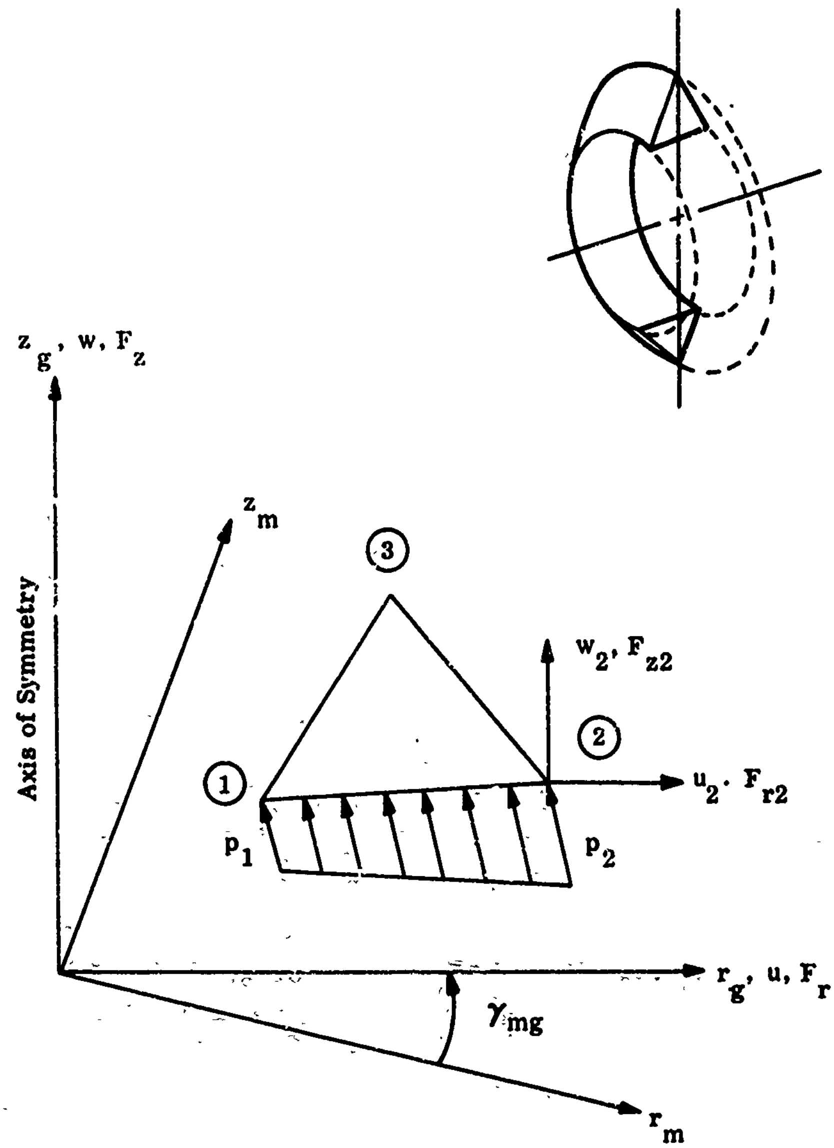


Figure II-17 Triangular Cross Section Ring Element Description

d. Toroidal Thin Shell Ring (Ident. No. 30)

The toroidal thin shell element is recommended for the idealization of axisymmetric structures of arbitrary profile. Performance of the toroidal ring element is outstanding relative to the well known conic ring. The toroidal thin shell ring element representation is developed in detail in Reference 11, and is shown in Figure II-18. The toroidal thin shell ring discrete element is written with respect to a toroidal coordinate system. In general, the cross-section of the toroidal segment is circular. Specialization to conic and cylindrical shapes is automatically accounted for in the MAGIC System. The geometric shape of the element is specified by the coordinates and surface orientation at its edge grid rings. The thickness of the element is assumed constant.

The subject element is written to accommodate orthotropic materials. Axes of orthotropy are assumed to coincide with the principal axes of the element. Material properties are taken to be constant throughout the element. The temperature of reference is the average of the data specified element node point temperatures.

The mathematical model for the toroidal ring embodies coupled representation of membrane and flexure action. A state of plane stress is assumed in formulating the continuum mechanics model. Discretization is effected by the construction of assumed modes for displacement and applied loading functions.

An osculatory axisymmetric polynomial interpolation is taken to represent membrane displacement within the element. Transverse displacement is represented by a hyperosculatory interpolation function. Applied loadings are assumed to be constant over the element.

Deformation behavior of the toroidal ring element is described by the ten displacement degrees of freedom associated with the two grid rings which it connects. These degrees of freedom provide for a relatively high order of variation within the element. In virtue of this, stress resultants are exhibited at the two boundary rings and at the midspan of the element. The toroidal axes provide the frame of reference.

The following element matrices are provided for the Toroidal Thin Shell Ring in the MAGIC System.

Stiffness
Stress
Thermal Load
Distributed Loading (Pressure)
Consistent Mass

The Toroidal Ring Element is provided with a linearly varying pressure load.

Provision is made for pressure acting normal to the element. The Grid Point Pressure Data Form (Figure II-6) is provided to accept pressure loadings if they exist. On that Form provision is made for three possible input pressures per grid point, P_1, P_2, and P_3.

For the Toroidal Ring Element, pressure values correspond to pressures designated P_1 on the Grid Point Pressure Data Form. These pressure values are input in Columns 13-22. Pressures are defined as positive if acting in the positive local element Z direction (see Figure II-18).

A membrane thermal load matrix is also provided for the Toroidal Ring Element. The Grid Point Temperature Data Form (Figure II-7) is provided for the temperature values if they exist. In that section provision is made for three possible input temperatures, T_1, T_2, and T_3.

For the Toroidal Ring Element, the node point temperatures correspond to the temperatures designated T_1 and T_2 on the Grid Point Temperature Data Form. For each gridpoint, the temperature designated as T_1 corresponds to the inner temperature at node point (1) and is input in columns 13-22. The temperature designated as T_2 corresponds to the outer temperature at node point (1) and is input in columns 23-32 of the Grid Point Temperature Data Form. The program then averages the inner and outer temperatures given for each node point and uses this temperature as the representative node point temperature.

The input procedure for the Boundary Condition Section when using the Toroidal Ring merits special comment at this time. Figure II-19 shows a typical Boundary Condition Input Form. For the Toroidal Ring Element, the Boundary Condition Input requires three extra fields giving a total of nine (9). It is important to note, however, that only five (5) of these degrees of freedom exist as shown in the figure.

The first six degrees of freedom may be considered as the degrees of freedom which are considered in the normal manner. These six degrees of freedom may be based on Global coordinates or on element system coordinates. In the element system, $X(\xi)$ is tangential and positive in the direction from element point (1) to element point (2) and Z is normal to the element, with positive Z being defined as though the Global system were rotated about the $Y(\theta)$ axis so as to align with the element $X(\xi)$ axis (see Figure II-18). In order to invoke the element axis option for the Toroidal Ring, a special code is employed which is described subsequently.

The remaining degrees of freedom (u' and w'') are always referenced to the element system. Physically u' is difficult to define but can be thought of as the rate of change of arc length (at symmetric boundaries, $u' = 0$, otherwise $u' = 1$;) w'' is the curvature defined in the element system at the point in question. Restraint ($w'' = 0$), implies that the curvature is zero. No restraint ($w'' = 1$) implies that the curvature is permitted to change. In general, it is recommended that $w'' = 1$ except at symmetric or rigidly fixed boundaries where $w'' = 0$.

The Element Control Data which is required for the Toroidal Thin Shell Ring Element is as follows (see Figure II-13).

Element Number - (Cols. 7-10)

Refer to Element Control Section

Plug Number - (Cols. 11-12)

The Toroidal Ring is identified as Number 30.

Material Number - (Cols. 13-18)

Refer to Element Control Section

Temperature Interpolate Option - (Col. 19)

The Toroidal Ring is designated by 2 node points. If the User desires to exercise the Temperature Interpolate Option a '1' is entered in Column 19.

Material Temperature - (Cols. 20-27)

Refer to Element Control Section

Repeat Element Matrices - (Col. 28)

Refer to Element Control Section

Element Input - (Col. 29)

The Toroidal Ring Element always requires Element Input, therefore an 'X' is always placed in column 29 when a Toroidal Ring Element is being employed.

The following Element Input is required when using the Toroidal Ring Element (refer to Element Input Section). From the pre-labeled input data form it is seen that the Element Input locations are labeled A, B, C, D, E, F with each item contained in a ten column field.

The Element Input for the Toroidal Ring consists of the following information.

Location A - (Cols. 13-22)

Element Thickness (t)

Location B - (Cols. 23-32)

TCØ - This is a control input which changes the axis of reference from Global to element.

(a) Global - (TCØ = 0.0)

If the User desires to have the displacement behavior referenced to the Global system of reference, then the code 0.0 is entered in this location.

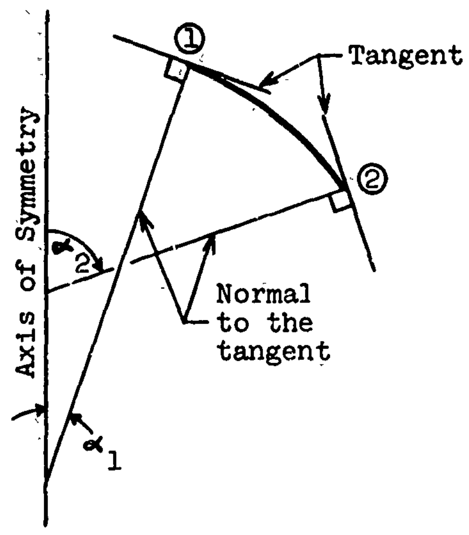
(b) Element - (TCØ = -1.0)

If the User desires to have the displacement behavior referenced to the element system (normal and tangential at point in question) then the code -1.0 is entered in this location. If the code -1.0 is used, then External Loads (if any exist) <u>must</u> be entered in the element system of reference. Provision is made for these External Loads on the External Grid Point Loads Data Form (Figure II-12).

It is important to note that <u>all</u> elements must be referenced to the same system, i.e., in any analysis which involves Toroidal Rings either the Global or element system must be used exclusively, as a frame of reference. <u>There can be no mixing of the systems</u>.

Location C - (Cols. 33-42)

Alpha 1 - (α_1) - Referring to the sketch, α_1 is defined as the angle measured in degrees from the axis of symmetry to a line which is perpendicular to the tangent to the surface at node point ①



Location D - (Cols. 43-52)

Alpha 2 - (α_2) - Referring to the sketch, α_2 is defined as the angle measured in degrees from the axis of symmetry to a line which is perpendicular to the tangent to the surface at node point 2 .

Note that for Conic Ring idealizations, $\alpha_1 \equiv \alpha_2$

The above is the required Element Input for the Toroidal Ring.

Returning to the Element Control Data Section, the list of data items continues as follows:

Interpolated Input Print - (Col. 30)

Element Matrix Print - (Col. 31)

Full Print - (Col. 32)

Refer to Element Control Section

Number of Input Nodes - (Cols. 33-34)

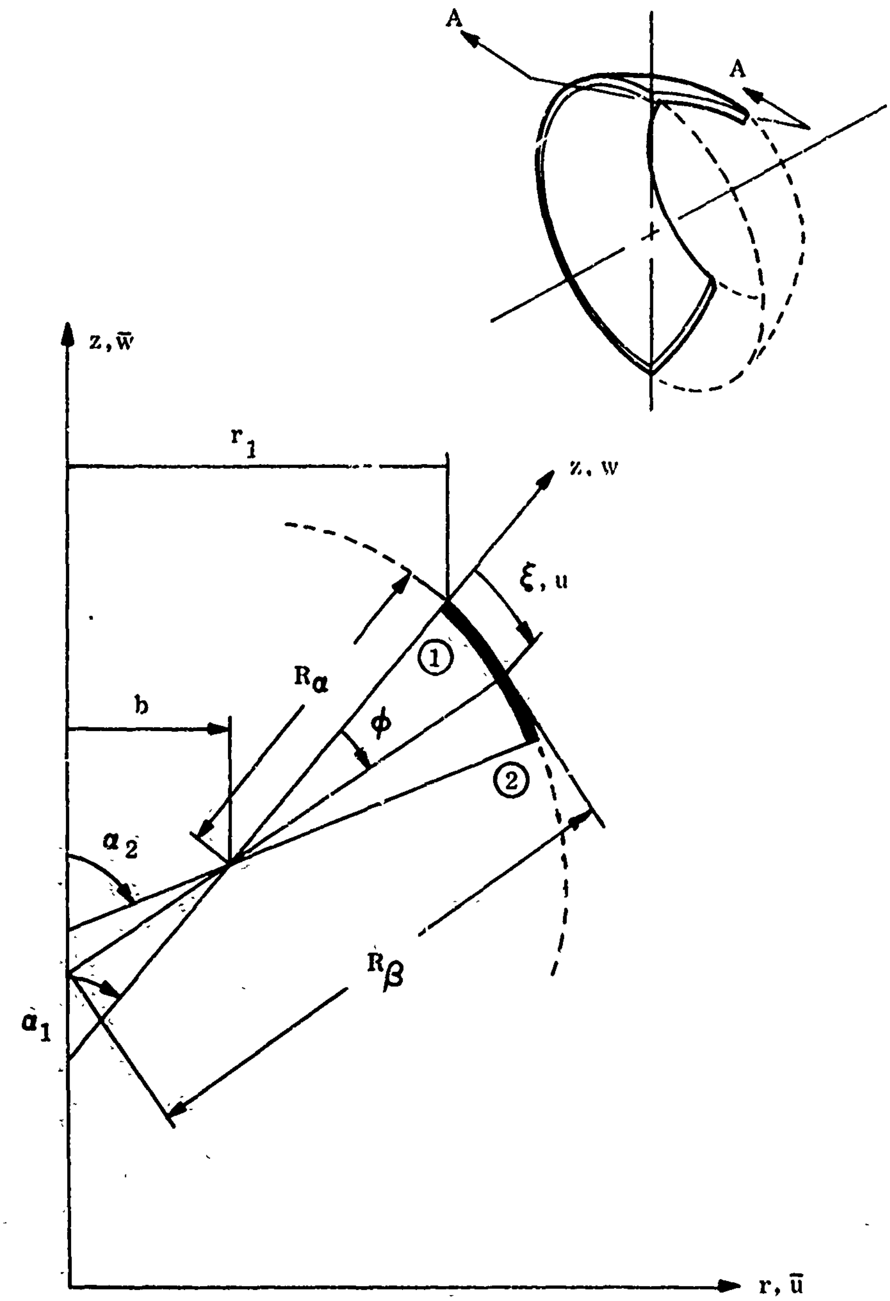
The Toroidal Thin Shell Element is always defined by 2 node points.

Pressure Suppression Option (Col. 35)

Refer to Element Control Section.

Node Points - (Cols. 36-71)

The two node points which define each Toroidal Thin Shell Ring Element are entered in these locations.



Section A-A

Figure II-18 Toroidal Thin Shell Ring Representation

BOUNDARY CONDITIONS

INPUT CODE -	
	0 - No Displacement Allowed
	1 - Unknown Displacement
	2 - Known Displacement

1	2	3	4	5	6	
B	O	U	N	D		(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	θx	θy	θz	1	2	3	
13	14	15	16	17	18	19	20	21	
U	0	W	0	θy	0	U'	0	W''	(/)

LISTED INPUT

Grid Point Number					Repeat										
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
															(/)
															(/)
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Figure II-19 BOUNDARY CONDITION INPUT FOR TOROIDAL RING

e. Quadrilateral Thin Shell (Ident. No. 21)

The quadrilateral thin shell element is recommended for use as the basic building block for membranes, plates, and shells. The triangular thin shell element is a compatible companion element useful in regions of irregularity and prominent double curvature. The quadrilateral thin shell element representation is developed in detail in Reference 12 and is shown in Figure II-20.

The shape of the general quadrilateral element is defined by the coordinates of the four corner points. It is a zero curvature element. The plane of the element is determined by its first three corner point coordinates.

The subject element is a thin shell element in that both membrane and flexure action are represented. Referenced to axes in the plane of the element, the membrane and flexure representations are uncoupled. Optional generation of either or both of the representations is controlled by the provision of associated effective thicknesses. The distinct membrane and flexure effective thicknesses are assumed constant over the plane of the element.

Under normal circumstances, four corner points and four midside points participate in establishing continuous connection of the quadrilateral thin shell element with adjacent elements. Used in this way input data volume is reduced and accuracy is enhanced. An option is provided to suppress the midside nodes individually if associated complexities arise in grid refinement or nonstandard connections with adjacent elements. Invoking this suppression option causes linear variation to be imposed on the specified midside variables.

The quadrilateral thin shell element, is written to accommodate anisotropy of mechanical and physical material properties. Orientation of material axes is data specified. Temperature referenced material properties, selected from the materials library, are assumed constant over the element.

A linear generalized Hooke's law is employed for the equations of state. Three options are provided; namely, conventional plane stress, corrected plane stress, and restricted plane strain.

The element formulation is discretized by the construction of mode shapes. Membrane displacements within the subject element are approximated by quadratic polynomials. Transverse displacement is represented by cubic polynomials. A linear variation is provided for midplane and gradient variations in thermal loading. Other element loadings such as pressure are assumed constant over the element. Deformation behavior of the quadrilateral thin shell element is described by the displacement degrees of freedom associated with the gridpoints which it connects.

The variation in strain within the element which is permitted by the assumed displacement functions leads to similar stress variation. Advantage is taken of this by exhibiting predicted stress resultants at the four corners as well as at the center of the element. Inplane and normal direct, shear, and bending stress resultants are included. The display of stresses implies a set of axes of reference. These axes are data specified.

The following element matrices are provided for the Quadrilateral Thin Shell Element in the MAGIC System.

Stiffness
Stress
Thermal Load
Distributed Loading (Pressure)
Mass

Referring to Figure II-20, it is seen that in general the Quadrilateral Thin Shell Element is defined by eight node points. There is an option in the program, however, which allows the User to suppress the midside node points individually if desired.

When defining the element, the first four node points determine the corner points of the element. The midside nodes are then numbered with the first entry being that midside node which falls between the first two corner points. Referring to the figure, the element would be numbered as follows:

1, 2, 3. 4, 5, 6, 7, 8

If it were desired to suppress mid-side node #6, the element would be numbered in the following manner (based on Figure II-20).

1, 2, 3, 4, 5, 0, 7, 8

This suppression causes linear variation to be imposed on the specified midside variables.

The element geometric axes (X_g, Y_g, Figure II-20) have their origin at the intersection of the diagonals of the quadrilateral thin shell element. The positive direction of the X_g axis of the element is defined by the line which connects the origin of the (X_g, Y_g) axis to node point 1 of the element as shown in the figure. The ($X_g - Y_g$) plane of the element is determined by the first three corner point coordinates. A material axes (X_m, Y_m) is also provided for this element. The angle (γ_{mg}) between the material and element geometric axes is considered positive wher measured in a counter-clockwise direction from X_m to X_g.

With respect to the element geometric axes, the corner grid points include the degrees of freedom u, v, w, θ_x and θ_y. A reduced set of degrees of freedom is associated with the midside grid points; namely, u, v and θ_n (normal slope). In general, transformation to global or grid point axes reference systems tends to fill these sets of degrees of freedom to u, v, w, θ_x, θ_y, θ_z for the corner grid points and to u, v, w, θ_n, 0, 0 (θ_n is not transformed) for the midside grid points. It is for the Analyst to decide, of course, whether or not these additional terms lead to bona-fide degrees of freedom in the assembled structure. The User should also note that on the Boundary Condition Data Form (Figure II-10). Whenever θ_n (θ_{normal}) is being considered, then the proper input code (either 0, 1, or 2) is always entered in the location which is normally reserved for the θ_x entry (Column 16).

The Grid Point Coordinate Data Form (Figure II-5) is provided for input of the coordinates which define the elements. Grid point coordinates for midside nodes are not necessary input since the program calculates these coordinates automatically.

The Quadrilateral Thin Shell Element is provided with a constant normal pressure load. The Grid Point Pressure Data Form (Figure II-6) is provided for this pressure loading if it exists. On that form provision is made for three possible input pressures per grid point, P_1, P_2, and P_3.

For the Quadrilateral Thin Shell Element the input pressures correspond to pressures designated P_1 on the Grid Point Pressure Data Form. These pressure values are input in Columns 13-22. The pressure is defined as positive when acting in the direction of positive element Z_g direction.

A linear variation is provided for midplane and gradient variations in thermal loading. The Grid Point Temperature Data Form (Figure II-7) is provided to input node point temperatures and/or temperature gradients. For the Quadrilateral Thin Shell Element, the midplane node point temperatures correspond to the temperature designated T_1 on the Grid Point Temperature Data Form. These temperature values are input in Columns 13-22 of that Form.

Provision for a temperature gradient through the thickness of the Quadrilateral Thin Shell is also provided. This gradient is defined as positive when the temperature is increasing through the thickness in the positive element Z_g direction. If temperature gradients through the thickness are present, the value of the gradient at each grid point is entered in the location set aside for the quantity, T_2 (Cols. 23-32) on the Grid Point Temperature Data Form. The gradient is entered in the following manner.

$$T_2 = \frac{\Delta T}{t}$$

where

ΔT = Change in temperature through the thickness of the element

t = Thickness of element

Note that the sign of T_2 depends upon the direction of the gradient as pointed out above.

The Element Control Data which is required for the Quadrilateral Thin Shell Element is as follows. (See Figure II-13).

Element Number - (Cols. 7-10)

Refer to Element Control Section

Plug Number - (Col. 11-12)

The Quadrilateral Thin Shell Element is identified as Number 21.

Material Number - (Cols. 13-18)

Refer to Element Control Section

Temperature Interpolate Option - (Col. 19)

If the User exercises this option by not making an entry in Column 19, the program will average the eight node point temperatures of the element and use this average temperature when establishing material properties from the material tape. This means that temperatures for all eight node points (including the mid-side nodes) must be entered on the Grid Point Temperature Data Form (Figure II-7). If the User wishes to employ a specified number of node points, n, in the averaging process ($n<8$) then this number is entered in Column 19 and the first n node points entered in Columns 36-71 will be used for the averaging process. If a '1' is entered in this location the program will use the Material Temperature entered in Columns 20-27 when establishing material properties from the material tape.

Material Temperature - (Cols. 20-27)

Repeat Element Matrices - (Col. 28)

Refer to Element Control Section

Element Input - (Col. 29)

The Quadrilateral Thin Shell Element always requires Element Input therefore an 'X' is always placed in Column 29 when a Quadrilateral Thin Shell Element is being employed.

The following Element Input is required when using the Quadrilateral Thin Shell Element (Refer to the Element Input Section). From the Element Input Data Form it is seen that the Element Input Locations are labeled A, B, C, D, E, F, with each item contained in a ten column field.

Location A - (Cols. 13-22)

Membrane Thickness (t_m) -

For the Quadrilateral Thin Shell Element, both membrane and flexural action are represented. Optional generation of either or both representations is controlled by the provision of associated membrane and flexure thickness. If the User desires to do a membrane problem, the membrane thickness is input. If membrane behavior is not to be considered, the associated membrane thickness is not input. Note also that mass matrix generation is based on the element membrane thickness.

Location B - (Cols. 23-32)

Flexural Thickness - (t_f) -

If the User desires to do a flexure problem, the effective flexure thickness must be entered. Omission of this thickness degenerates the problem into one of pure membrane behavior. Since flexure and membrane behavior are uncoupled both can be run consecutively if desired.

Location C - (Cols. 33-42)

Material Axes Angle - (Gamma) -

Since the Quadrilateral Thin Shell Element is written to accommodate anisotropy of mechanical and physical properties, provision is made in the program for differences in orientation of material and element geometric axes for an element. The User inputs the angle between the material axis (X_m) and the element geometric axis (X_g) with this angle being measured in a counterclockwise direction from the material axis (X_m) to the element geometric axis (X_g). This angle (γ_{mg}) is input in degrees.

Location D - (Cols. 43-52)

Types of Solution:

(a) Corrected Plane Stress (Code 0.0) - The corrected plane stress solution is one in which the stress in the out of plane direction (σ_z) is set equal to zero but the full material properties matrix is used. That is, the effect of transverse properties on the in-plane stresses are included. Such effects are negligible for most practical materials.

(b) Restricted Plane Strain (Code 1.0) - The restricted plane strain solution is one in which the strain in the out of plane direction (ϵ_z), is set equal to zero.

(c) Conventional Plane Stress (Code 2.0) - The conventional plane stress solution is one in which the stress in the out of plane direction (σ_z), is set equal to zero and the effect of transverse properties on the in-plane stresses are not included.

Location E - (Cols. 53-62)

Eccentricity (ECC) -

The eccentricity is defined as the distance measured from the neutral axis of the eccentrically placed element to the midplane of the reference element. The sign of the eccentricity is taken to be positive when the direction specified from the eccentric element to the reference element is in the positive local element direction.

The above is the Element Input required for the Quadrilateral Thin Shell Element. Returning to the Element Control Data Section, the list of data items continues as follows:

$\left.\begin{array}{l}\text{Interpolated Input Print - (Col. 30)}\\ \text{Element Matrix Print - (Col. 31)}\\ \text{Full Print - (Col. 32)}\end{array}\right\}$ Refer to Element Control Section

Number of Input Nodes - (Cols. 33-34)

The Quadrilateral Thin Shell Element is always defined by 8 input nodes.

Pressure Suppression Option (Col. 35)

Refer to Element Control Section.

Node Points - (Cols. 36-71)

In general the Quadrilateral Thin Shell Element is defined by 8 node points. The User, however, has the option to suppress the mid-side nodes individually if desired. Referring to Figure II-13, it is seen that 12 locations are set aside for node point entries. The first 8 locations are set aside for the four corner points and four mid-side nodes respectively.

Locations 9 and 10 - (Cols. 60-65)

Most finite elements accommodate anisotropic materials. Axes of reference must be specified for material properties. This is accomplished through specification as element data, of coordinate points defining the material axes. These axes are defined by inputting the applicable set of coordinates in these locations. These coordinates define the X axis for material property definition. This device may also be used effectively to define stress output direction and the same two points used for the reference element can be used for each following element so that the output has a common reference.

Locations 11 and 12-(Cols. 66-71)

A specification of stress values implies a set of reference axes. The axes of reference, are determined with the provision of an element stress matrix. Frequently axes of reference convenient for formulation are not convenient for interpretation of stresses. The problem is resolved by data specification of stress axes. This is accomplished

through specification as element data, of coordinate points which define the direction of the (X) stress axis. With this definition the stresses in the other directions retain their proper orientation with respect to this axis.

The stress axis determination is element related and therefore if locations 11 and 12 are used for stress directions, then each element must be considered separately and node points related to that particular element are used in determining stress direction.

<u>REMEMBER:</u>

(a) If all four mid-side nodes were suppressed only the first four locations would be needed. If mid-side nodes are suppressed individually then zeros are input in the location pertaining to that particular point.

(b) The stress axis determination is element related and therefore if locations 11 and 12 are used for stress directions, then each element must be considered separately and node points related to that particular element are used in determining stress direction.

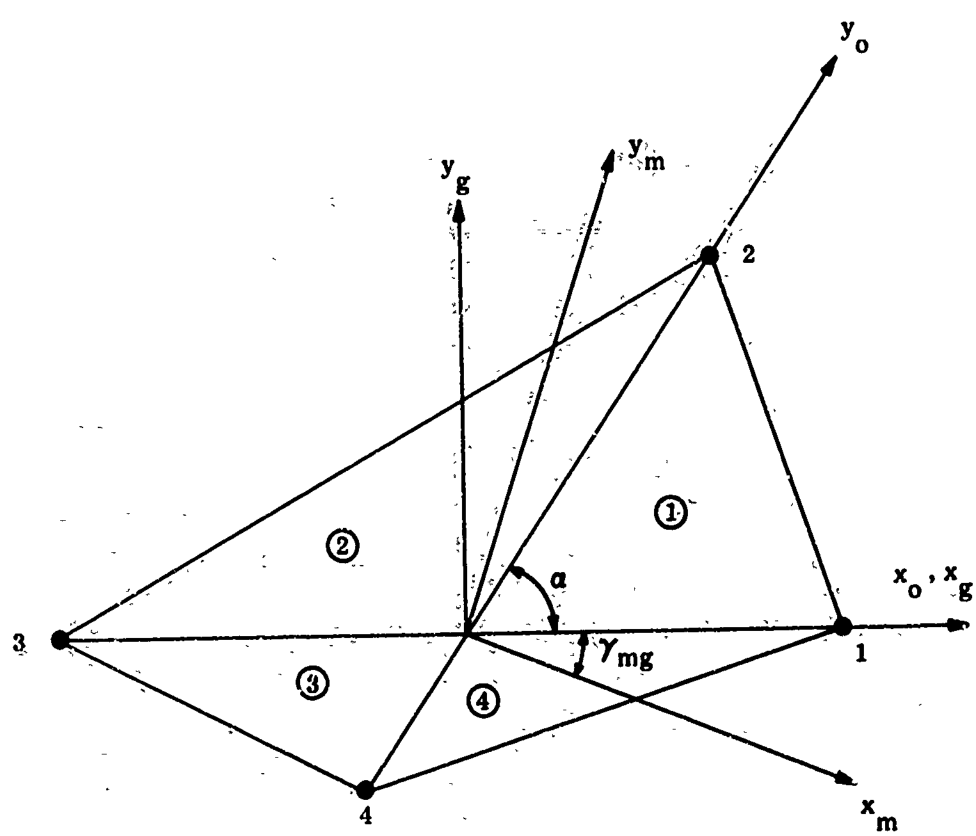


Figure II-20 Quadrilateral Thin Shell Element Representation

f. Triangular Thin Shell (Ident. No. 20)

The Triangular thin shell element is recommended for use as the basic building block for most doubly curved shells. Additionally, it is useful in combination with the quadrilateral thin shell element for dealing with irregular geometries of all membrane, plate, and shell structures. The triangular thin shell element representation is developed in detail in Reference 13, and is shown in Figure II-21.

The shape of the general triangular element is defined by the coordinates of the three corner points. It is a zero curvature element. The plane of the element is determined by the three cornerpoint coordinates.

The subject element is a thin shell element in that both membrane and flexure action are represented. Referenced to axes in the plane of the element, the membrane and flexure representations are uncoupled. Optional generation of either or both of the representations is controlled by the provision of associated effective thicknesses. The distinct membrane and flexure effective thicknesses are assumed constant over the plane of the element.

Under normal circumstances, three corner points and three midside points participate in establishing continuous connection of the triangular thin shell element with adjacent elements. Used in this way input data volume is reduced and accuracy is enhanced. An option is provided to suppress the midside nodes individually if associated complexities arise in grid refinement or nonstandard connections with adjacent elements. Invoking this suppression option causes linear variation to be imposed on the specified midside variables.

The triangular thin shell element is written to accommodate anisotropy of mechanical and physical material properties. Orientation of material axes is data specified. Temperature referenced material properties, selected from the materials library, are assumed constant over the element.

A linear generalized Hooke's Law is employed for the equations of state. Three options are provided; namely, conventional plane stress, corrected plane stress, and restricted plane strain.

The element formulation is discretized by the construction of mode shapes. Membrane displacements within the subject element are approximated by quadratic polynomials. Transverse displacement is represented by cubic polynomials. A linear variation is provided for midplane and gradient variations in thermal loading. Other element loadings such as pressure are assumed constant over the element.

Deformation behavior of the triangular thin shell element is described by the displacement degrees of freedom associated with the grid points which it connects.

The variation in strain within the element which is permitted by the assumed displacement functions leads to similar stress variation. Advantage is taken of this by exhibiting predicted stress resultants at the three corners as well as at the center of the element. Inplane and normal; direct, shear, and bending stress resultants are included. The display of stresses implies a set of axes of reference. These axes are data specified.

The following element matrices are provided for the Triangular Thin Shell Element in the MAGIC System.

Stiffness
Stress
Thermal Load
Distributed Loading (Pressure)
Mass

Referring to Figure II-21, it is seen that in general the Triangular Thin Shell Element is defined by six node points. There is an option in the program, however, which allows the User to suppress the midside node points individually if desired.

When defining the element, the first three node points determine the corner points of the element. The midside nodes are then numbered with the first entry being that midside node which falls between the first two corner points. Referring to the figure, the element would be numbered as follows

1, 2, 3, 4, 5, 6

If it were desired to suppress mid-side node #4, the element would be numbered in the following manner (based on Figure II-21)

1, 2, 3, 0, 5. 6

This suppression causes linear variation to be imposed on the specified midside variables.

The element geometric axes (X_g, Y_g, Figure II-21) have their origin at the intersection of the lines which connect the centroid to the vertices. The positive direction of the X_g axis is defined by the line which connects the origin of the (X_g, Y_g) axis to node point ① of the element as shown in the figure. The (X_g-Y_g) plane of the element is determined by the three corner point coordinates. A material axis (X_m, Y_m) is also provided for this element. The angle (γ_{mg}) between the material and element geometric axis is considered positive when measured in a counter-clockwise direction from X_m to X_g.

With respect to the element geometric axes, the corner grid points include the degrees of freedom u, v, w, θ_x and θ_y. A reduced set of degrees of freedom is associated with the midside grid points; namely, u, v and θ_n (normal slope). In general, transformation to global or grid point axes reference systems tends to fill these sets of degrees of freedom to u, v, w, θ_x, θ_y, θ_z for the corner grid points and to u, v, w, θ_n, 0, 0 (θ_n is not transformed) for the midside grid points. It is for the Analyst to decide, of course, whether or not these additional terms lead to bona-fide degrees of freedom in the assembled structure. The User should also note that on the Boundary Condition Data Form (Figure II-10). Whenever θ_n (θ_{normal}) is being considered, then the proper input code (either 0, 1, or 2) is always entered in the location which is normally reserved for the θ_x entry (Column 16).

The Grid Point Coordinate Data Form (Figure II-5) is provided for input of the coordinates which define the elements. Grid point coordinates for mid-side nodes are not necessary input since the program calculates these coordinates automatically.

The Triangular Thin Shell Element is provided with a constant normal pressure load. The Grid Point Pressure Data Form (Figure II-6) is provided for this pressure loading if it exists. On that form provision is made for three possible input pressures per grid point P_1, P_2, and P_3.

For the Trinagular Thin Shell Element the input pressures correspond to pressures designated P_1 on the Grid Point Pressure Data Form. These pressure values are input in Columns 13-22. The pressure is defined as positive when acting in the direction of positive element Z_g direction.

A linear variation is provided for midplane and gradient variations in thermal loading. The Grid Point Temperature Data Form (Figure II-7) is provided to input node point temperatures and/or temperature gradients. For the Triangular Thin Shell Element, the midplane node point temperatures correspond to the temperature designated T_1 on the Grid Point Temperature Data Form. These temperature values are input in Columns 13-22 of that Form.

Provision for a temperature gradient through the thickness of the Triangular Thin Shell is also provided. This gradient is defined as positive when the temperature is increasing through the thickness in the positive element Z_g direction. If temperature gradients through the thickness are present, the value of the gradient at each grid point is entered in the location set aside for the quantity, T_2 (Cols. 23-32) on the Grid Point Temperature Data Form. The gradient is entered in the following manner.

$$T_2 = \frac{\Delta T}{t}$$

where

ΔT = Change in temperature through the thickness of the element

t = Thickness of element

Note that the sign of T_2 depends upon the direction of the gradient as pointed out above.

The Element Control Data which is required for the Triangular Thin Shell Element is as follows. (See Figure II-13).

<u>Element Number - (Cols. 7-10)</u>

Refer to Element Control Section

<u>Plug Number - (Col. 11-12)</u>

The Triangular Thin Shell Element is identified as Number 20.

<u>Material Number - (Cols. 13-18)</u>

Refer to Element Control Section

<u>Temperature Interpolate Option - (Col. 19)</u>

If the User exercises this option by <u>not</u> making an entry in Column 19, the program will average the <u>six</u> node point temperatures of the element and use this average temperature when establishing material properties from the material tape. This means that temperatures for all six node points (including the mid-side nodes) must be entered on the Grid Point Temperature Data Form (Figure II-7). If the User wishes to employ a specified number of node points, n, in the averaging process ($n < 6$) then this number is entered in Column 19 and the first n node points entered in Columns 36-71 will be used for the averaging process. If a '1' is entered in this location the program will use the Material Temperature entered in Columns 20-27 when establishing material properties from the material tape.

<u>Material Temperature - (Cols. 20-27)</u>

Refer to Element Control Section

<u>Repeat Element Matrices - (Col. 28)</u>

Refer to Element Control Section

<u>Element Input - (Col. 29)</u>

The Triangular Thin Shell Element <u>always</u> requires Element Input therefore an 'X' is always placed in Column 29 when a Triangular Thin Shell Element is being employed.

The following Element Input is required when using the Triangular Thin Shell Element (Refer to the Element Input Section). From the Element Input Data Form it is seen that the Element Input Locations are labeled A, B, C, D, E, F with each item contained in a ten column field.

Location A - (Cols. 13-22)

Membrane Thickness (t_m) -

For the Triangular Thin Shell Element, both membrane and flexural action are represented. Optional generation of either or both representations is controlled by the provision of associated membrane and flexure thickness. If the User desires to do a membrane problem, the membrane thickness is input. If membrane behavior is not to be considered, the associated membrane thickness is not input. Note also that mass matrix generation for this element is based on the element membrane thickness.

Location B - (Cols. 23-32)

Flexural Thickness (t_f)

If the User desires to do a flexure problem, the effective flexure thickness must be entered. Omission of this thickness degenerates the problem into one of pure membrane behavior. Since flexure and membrane behavior are uncoupled both can be run consecutively if desired.

Location C - (Cols. 33-42)

Material Axes Angle - (Gamma) -

Since the Triangular Thin Shell Element is written to accommodate anisotropy of mechanical and physical properties provision is made in the program for differences in orientation of material and element geometric axes for an element. The User inputs the angle between the material axis (X_m) and the element geometric axis (X_g) with this angle being measured in a counterclockwise direction from the material axis (X_m) to the element geometric axes (X_g).

This angle (γ_{mc}) is input in degrees.

Location D - (Cols. 43-52)

Types of Solution:

(a) Corrected Plane Stress (Code 0.0) - The corrected plane stress solution is one in which the stress in the out of plane direction (σ_z) is set equal to zero but the full material properties matrix is used. That is, the effect of transverse properties on the in-plane stresses are included. Such effects are negligible for most practical materials.

(b) Restricted Plane Strain (Code 1.0) - The restricted plane strain solution is one in which the strain in the out of plane direction (ϵ_z) is set equal to zero.

(c) Conventional Plane Stress (Code 2.0) - The conventional plane stress solution is one in which the stress in the out of plane direction, (σ_z) is set equal to zero and the effect of transverse properties on the in-plane stresses are not included.

Location E - (Cols. 53-62)

Eccentricity (ECC) -

The eccentricity is defined as the distance measured from the neutral axis of the eccentrically place element to the midplane of the reference element. The sign of the eccentricity is taken to be positive when the direction specified from the eccentric element to the reference element in the positive local element direction.

The above is the Element Input required for the Triangular Thin Shell Element. Returning to the Element Control Data Section, the list of data items continues as follows.

Interpolated Input Print - (Col. 30)	Refer to Element Control Section
Element Matrix Print - (Col. 31)	
Full Print - (Col. 32)	

Number of Input Nodes - (Cols. 33-34)

The Triangular Thin Shell Element is always defined by 6 Input Nodes.

Pressure Suppression Option (Col. 35)

Refer to Element Control Section.

Node Points - (Cols. 36-71)

In general the Triangular Thin Shell Element is defined by six node points. The User, however, has the option to suppress the mid-side nodes individually if desired. Referring to Figure II-13, it is seen that 12 locations are set aside for node point entries. The first 6 locations are set aside for the three corner points and three-mid-side nodes respectively.

Locations 9 and 10 - (Cols. 60-65)

Most finite elements accommodate anisotropic materials. Axes of reference must be specified for material properties. This is accomplished through specification as element data, of co-ordinate points defining the material axes. These axes are defined by inputting the applicable set of coordinates in these locations. These coordinates define the X axis for material property definition. This device may also be used effectively to define stress output direction and the same two points used for the reference element can be used for each following element so that the output has a common reference.

Locations 11 and 12 - (Cols. 66-71)

A specification of stress values implies a set of reference axes. The axes of reference are determined with the provision of an element stress matrix. Frequently axes of reference convenient for formulation are not convenient for interpretation of stresses. The problem is resolved by data specification of stress axes. This is accomplished through specification as element data, of coordinate points which define the stress axes. The node points entered in these locations define the direction of the (X) stress axis. With this definition, the stresses in the other directions retain their proper orientation with respect to this axis.

REMEMBER:

(a) If all three mid-side nodes were suppressed only the first three locations would be needed. If mid-side nodes are suppressed individually then zeros are input in the location pertaining to that particular point.

(b) The stress axis determination is element related and therefore if locations 11 and 12 are used for stress directions, then each element must be considered separately and node points related to that particular element are used in determining stress direction.

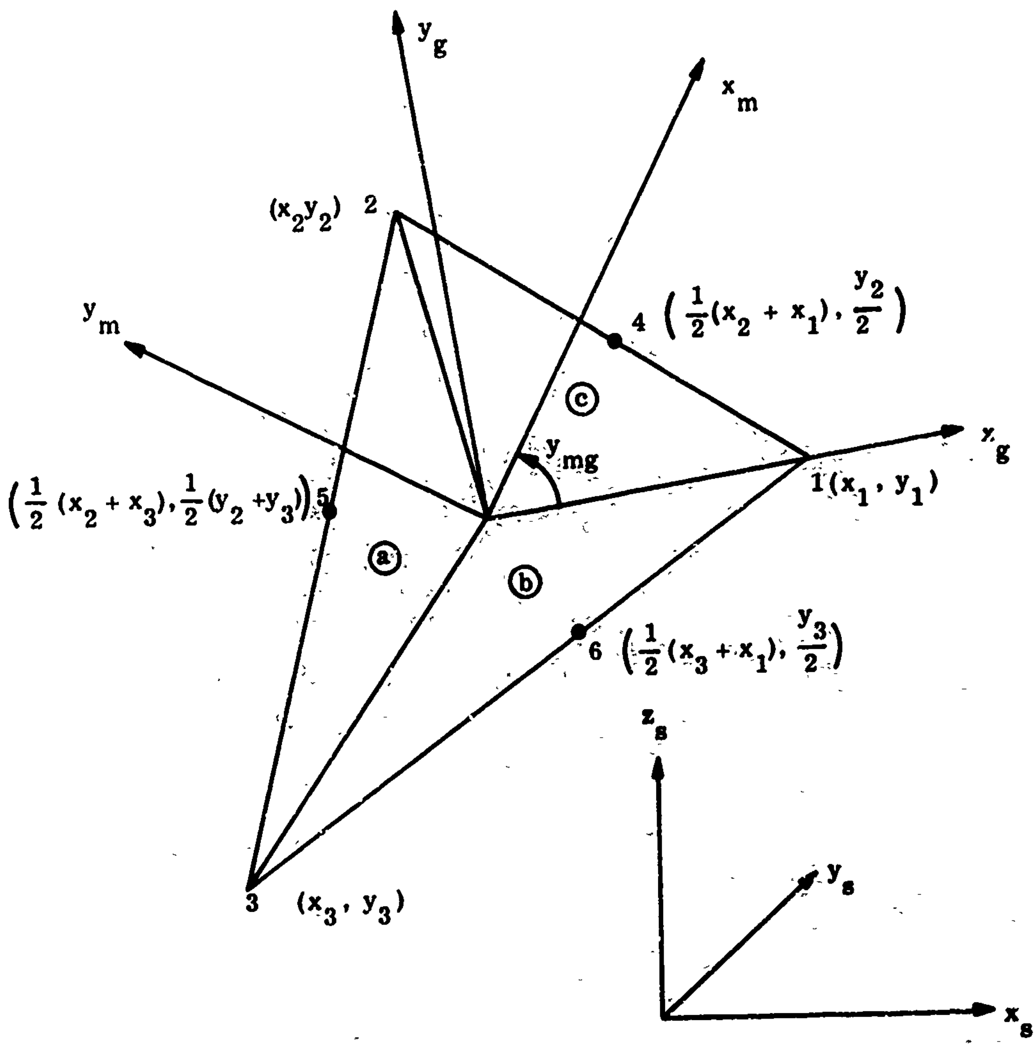


Figure II-21 Triangular Thin Shell Element Representation

g. Trapezoidal Cross-Section Ring (Core) (Ident. No. 41)

The trapezoidal cross-section ring discrete element, shown in Figure II-22a provides a powerful tool for the analysis of thick walled and solid axisymmetric structures of finite length and arbitrary profile. It may be used alone or if the problem dictates a highly irregular grid work it may be combined with the well known triangular ring element which is described in Reference For the analysis of solid structures, it can be combined with a core discrete element (Figure II-22 a) which is a specialization of the trapezoidal ring. A detailed development of the Trapezoidal Ring (and Core) Discrete Elements is presented in Reference 14.

The trapezoidal ring element representation is written with respect to cylindrical coordinate axes. The configuration of the element is completely defined by specifying radial and axial coordinates of the four corner points.

Cylindrical anisotropy is provided for in the mechanical and physical material properties of the ring element. Orientation of orthotropic axes in the (r, z) plane is data specified.

The element designation "ring" implies an axisymmetric geometric configuration. It has been further tacitly assumed that the applied loading is axisymmetric; it follows, as a consequence, that the displacement behavior is also axisymmetric.

A three dimensional axisymmetric stress state is assumed. Polynomial functions are employed for displacement mode shapes. A linearly varying thermal load is also provided for this element.

Deformation behavior of the trapezoidal ring is described by the eight displacement degrees of freedom associated with the four grid points which it connects. Element stress behavior is described by the state of stress predicted at the four corner points and at the center of the element. Radial, circumferential and axial stresses are predicted.

The following element matrices are provided for the Trapezoidal Cross-Section Ring (Core) Element representation in the MAGIC System

- Stiffness
- Stress
- Thermal Load
- Distributed Loading (Pressure)
- Consistent Mass

The trapezoidal cross-section ring element is numbered in the following manner. Referring to Figure II 22-(a), the element is numbered in a counter-clockwise manner when looking in the positive element Y (θ) direction. The element numbering must begin at the lower left hand corner of the element (① in Figure II-22a). The line connecting grid points ① and ② and the line connecting grid points ③ and ④ must both be parallel to the r-axis. This means that the Z coordinate for grid point ① is equal to the Z coordinate for grid point ②. This is also true for grid points ③ and ④.

When the core element specialization of the trapezoidal ring is used, the r coordinate associated with grid points ① and ④ is always equal to zero.

The Trapezoidal Cross-Section Ring Element is provided with a linearly varying pressure load whose positive definition is shown in Figure II-22(a). Provision is made for pressure loading on all four sides of the element.

The Grid Point Pressure Data Form (Figure II-6) is provided for entering these pressure loadings if they exist. For the Trapezoidal Cross-Section Ring Element, the input pressures correspond to the pressures designated P_1 and P_2 on the Grid Point Pressure Data Form. The pressures P_1 correspond to radial pressure acting on the element and are entered in Columns 13-22. The pressures P_2 correspond to axial pressure acting on the element and are entered in Columns 23-32.

A linearly varying thermal load vector is included in this element representation to accommodate thermal loading. The Grid Point Temperature Data Form (Figure II-7) is provided to input node point temperatures if thermal loading is present. For the Trapezoidal Ring Element, the node point temperatures correspond to the temperature designated T_1 on the Grid Point Temperature Data Form. These temperature values are input in Columns 13-22 of that Form.

The Element Control Data which is required for the Trapezoidal Ring Element is as follows: (See Figure II-13).

Element Number - (Cols. 7-10)

Refer to Element Control Section

Plug Number - (Cols. 11-12)

The Trapezoidal Cross-Section Ring (Core) Element is identified as Number 41.

Material Number - (Cols. 13-18)

Refer to Element Control Section

Temperature Interpolate Option - (Col. 19)

The Trapezoidal Ring Element is designated by 4 node points. If the User desires to exercise the Temperature Interpolate Option and average all four (4) of the node point temperatures, an entry is not made in Column 19. If the User desires to enter a material temperature in Cols. 20-27, a '1' is entered in Column 19.

Material Temperature - (Cols. 20-27)

Refer to Element Control Section

Repeat Element Matrices - (Col. 28)

Refer to Element Control Section

Element Input - (Col. 29)

The Trapezoidal Cross-Section Ring Element only requires Element Input under certain special conditions as follows: Referring to Figure II-22, it is seen that there is a possibility that in some cases the material axis, and element geometric axis of the element will not coincide. If this is the case, the Element Input (Figure II-14) required for the Trapezoidal Cross-Section Ring consists of the following:

Location A - (Cols. 13-22)

Material Axes Angle (Gamma - γ_{mg})

Since the Trapezoidal Cross-Section Ring Element is written to accommodate anisotropy of mechanical and physical properties, provision is made in the program for differences in orientation of material and element geometric axes for an element. The User inputs the angle between the element material axis (X_m) and the element geometric axis (X_g). The angle gamma (γ_{mg}) is input in degrees and is considered positive when measured from the material axes to the element geometric axes, in a counter-clockwise direction (Figure II-22(a).

Remember

Element Input is not required for the Trapezoidal Ring if the material and geometric axes coincide, i.e., $\gamma_{mg} = 0$.

Returning to the Element Control Data Section, the list of data items continues as follows:

Interpolated Input Print - (Col. 30)
Element Matrix Print - (Col. 31)
Full Print (Col. 32)

Refer to Element Control Section

Number of Input Nodes (Cols. 33-34)

The Trapezoidal Cross-Section Ring (Core) Element is always defined by 4 input nodes.

Pressure Suppression Option - (Col. 35)

Refer to Element Control Section

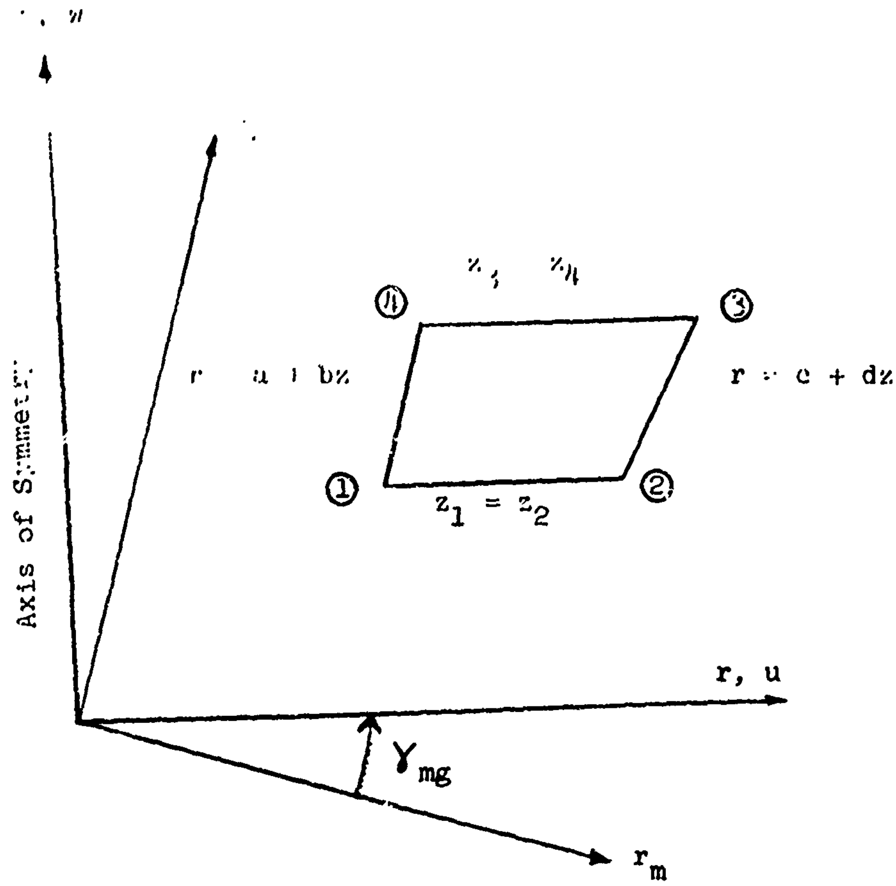
Node Points - (Cols. 36-71)

The four node points which define each Trapezoidal Ring are entered in the first four entries provided in the Node Point Section of the Element Control Data Form.

When using the Core Element specialization of the Trapezoidal Ring, the following guidelines are supplied:

(a) The radii of node points 1 and 4 for any particular Core Element must always be equal to zero (Grid Point Coordinate Section, Figure II-5).

(b) The radial displacement, u, at node points 1 and 4 must always be set equal to zero for any particular Core Element (Boundary Condition Section, Figure II-10).



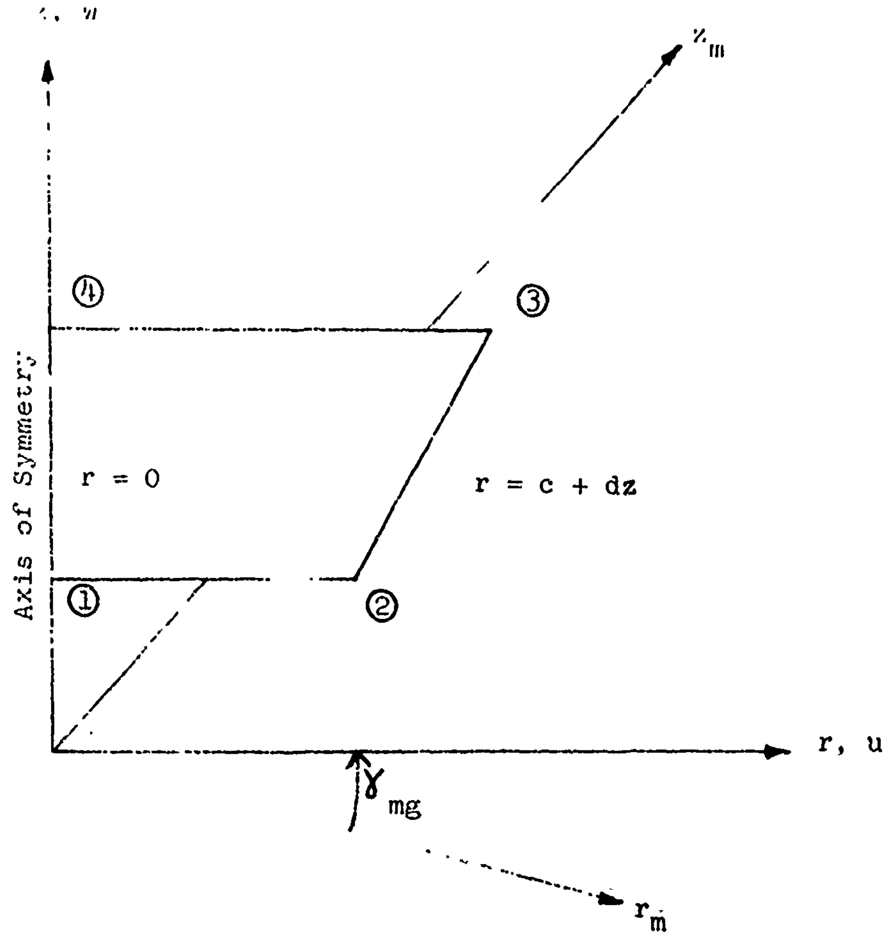
$$a = r_1 - \left(\frac{r_4 - r_1}{z_4 - z_1}\right) z_1$$

$$b = \frac{r_4 - r_1}{z_4 - z_1}$$

$$c = r_2 - \left(\frac{r_3 - r_2}{z_3 - z_2}\right) z_2$$

$$d = \frac{r_3 - r_2}{z_3 - z_2}$$

Figure II-22(a) - Trapezoidal Cross-Section Ring Element Description



Special Conditions On Core Element

(a) $r_1 \equiv r_4 \equiv 0$

(b) $u_1 \equiv u_4 \equiv 0$

Figure II-22(b) - Core Element Specialization of Trapezoidal Cross-Section Ring Element

h. Quadrilateral Plate (Ident. No. 28)

The quadrilateral plate element is recommended for use as the basic building block for membranes, plates and shells when performing an elastic stability analysis. The triangular plate element (Ident. No. 27) is a companion element useful in regions of irregularity and double curvature. The quadrilateral plate element is developed in detail in References 4 and 15 and is shown in Figure II-23.

The shape of the general quadrilateral plate is defined by the coordinates of the four corner points. It is a zero curvature element. The plane of the element is determined by its first three corner point coordinates.

Membrane and flexure action are uncoupled for this element. Optional generation of either or both of the representations is controlled by the provision of associated effective thicknesses. The distinct membrane and flexure thicknesses are assumed constant over the plane of the element.

Four corner points participate in establishing continuous connection of the quadrilateral plate element with adjacent elements.

A quadrilateral plate element is written to accommodate anisotropy of mechanical and physical properties. Temperature referenced material properties, selected from the materials library, are assumed constant over the element.

A linear generalized Hooke's law is employed for the equations of state. The conventional plane stress option is provided for this element.

The element formulation is discretized by the construction of mode shapes. Membrane stresses within the element are approximated by the following polynomials

$$\sigma_x = a_1 + a_2 y$$

$$\sigma_y = a_3 + a_4 x$$

$$\sigma_{xy} = a_5$$

Transverse displacement is represented by cubic polynomials.

Element stresses for the quadrilateral plate are predicted at the center of the element. Inplane and normal direct, shear and bending stress results are included. The display of stresses implies a set of reference axes. These axes are data specified.

The following element matrices are provided for the Quadrilateral Plate Element in the MAGIC System.

Stiffness
Stress
Thermal Load
Incremental Stiffness

A constant prestrain load vector is included in this element representation to accommodate thermal loading. The Grid Point Temperature Data Form (Figure II-7) is provided to input node point temperatures if thermal loading is present. For mid-plane (membrane) variations in thermal loading, the temperature input correspond to the temperatures designated T_1, on the Grid Point Temperature Data Form. These temperatures are input in Columns 13-22 of that form.

For flexural action, the gradient through the thickness is assumed constant. If temperature gradients through the thickness are present, the value of the gradient at each grid point is entered in the location set aside for the quantity, T_2 (Cols. 23-32) on the Grid Point Temperature Data Form. Thermal moments which arise from the gradients are then automatically defined by the System by prorating the distributed edge moments to the corners.

In the performance of elastic stability analyses using this element, the set of abstraction instructions as outlined in Section II.g.4 of this volume should be utilized. Consistent "initial stress" incremental stiffness matrices are generated using the membrane stress results (σ_x, σ_y, σ_{xy}) from the quadrilateral element in conjunction with the assumed transverse-displacement functions of the element, i.e.,

$$U = 1/2 \iint N_x \left(\frac{\partial w}{\partial x}\right)^2 + N_y \left(\frac{\partial w}{\partial y}\right)^2 + 2N_{xy}\left(\frac{\partial w}{\partial x} \frac{\partial w}{\partial y}\right)\Big] \partial x \partial y$$

The Element Control Data which is required for the Quadrilateral Plate Element is as follows: (See Figure II-13)

Element Number -(Cols. 7-10)

Refer to Element Control Section.

Plug Number - (Cols. 11-12)

The Quadrilateral Plate Element is identified as as Number 28.

Material Number - (Cols. 13-18)

Refer to Element Control Section

Temperature Interpolate Option - (Col. 19)

If the User exercises this option by not making an entry in Column 19, the program will average the four node point temperatures of the element and use this average temperature when establishing material properties from the material tape. If the User wishes to employ a specified number of node points, n, in the averaging process ($1 < n < 4$) then this number is entered in Column 19 and the first n node points entered in Columns 36-71 will be used for the averaging process. If a '1' is entered in this location, the program will use the Material Temperature entered in Columns 20-27 when establishing material properties from the material tape.

Material Temperature - (Col. 20-27)

Refer to Element Control Section

Repeat Element Matrices - (Col. 28)

Refer to Element Control Section

Element Input - (Col. 29)

The Quadrilateral Plate Element always requires element input, therefore, an 'X' is always placed in Column 29 when a quadrilateral plate element is employed.

The following Element Input is required when using the Quadrilateral Plate Element (Refer to the Element Input Section). From the Element Input Data Form it is seen that the Element Input Locations are labeled A, B, C, D, E, F, with each item contained in a ten column field.

Location A - (Cols. 13-22)

Membrane Thickness - (t_m)

For the Quadrilateral Plate Element, both membrane and Flexural action are represented. Optional generation of either or both representations is controlled by the provision of associated membrane and flexure thicknesses.

Location B - (Cols. 23-32)

Flexural Thickness - (t_f)

If the User desires to do a flexure problem, the effective flexure thickness must be entered. Omission of this thickness degenerates the problem into one of pure membrane behavior. Since flexure and membrane behavior are uncoupled, both can be run consecutively if desired. In performing an elastic stability (buckling) analyses both the membrane and flexure thickness are needed.

The above is the Element Input required for the Quadrilateral Plate Element. Returning to the Element Control Data Section, the list of data items continues as follows:

Interpolated Input Print - (Col. 30)

Refer to Element Control Section

Element Matrix Print - (Col. 31)

Refer to Element Control Section

Full Print - (Col. 32)

Refer to Element Control Section

Number of Input Nodes (Cols. 33-34)

The Quadrilateral Plate Element is always defined by 4 input nodes.

Pressure Suppression Option - (Col. 35)

Refer to Element Control Section

Node Points - (Cols. 36-71)

The Quadrilateral Plate Element is defined by 4 node points. Note that the first two node points called out for the element determine the positive local 'X' axis for stress output with the local 'Y' axis at the right angles pointing in the direction of the third note point.

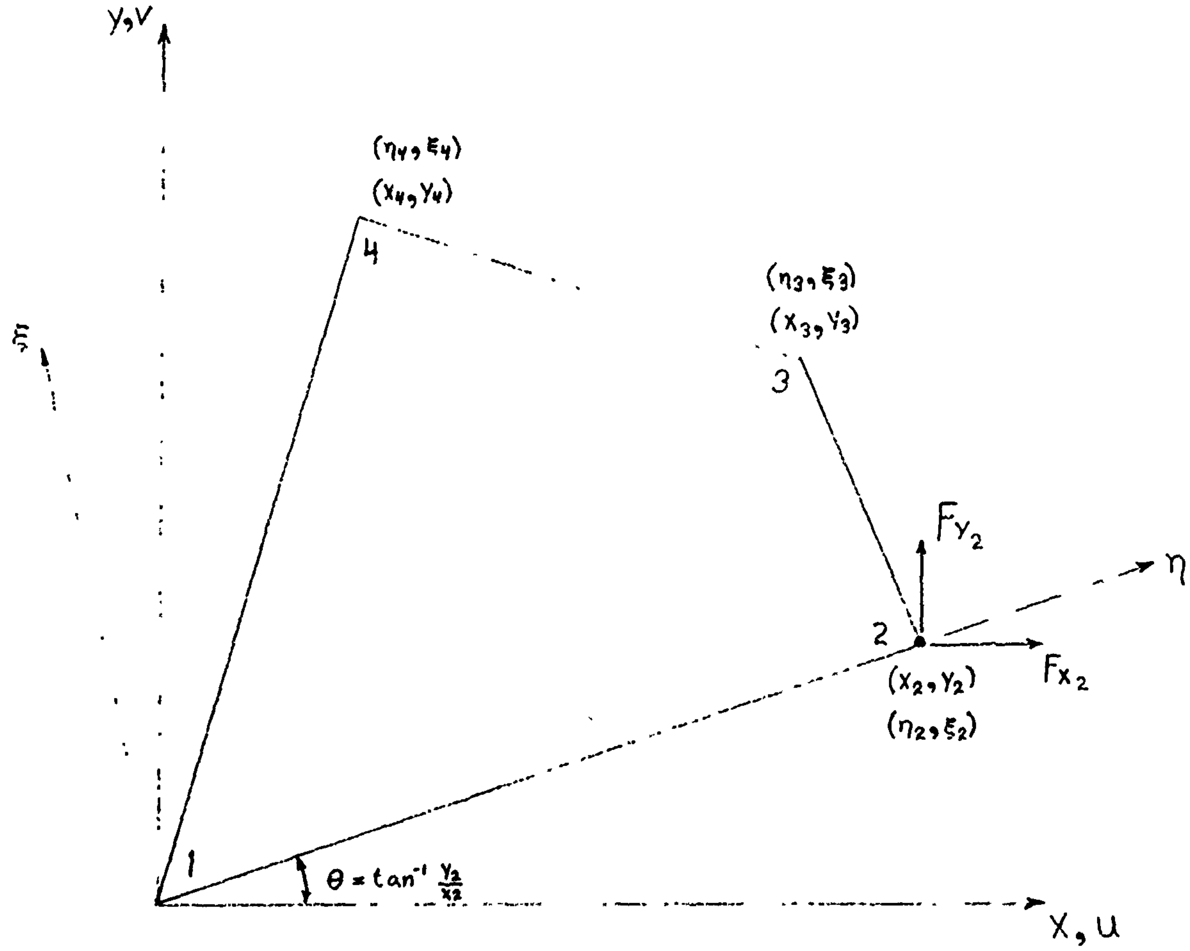


FIGURE II-23 QUADRILATERAL PLATE ELEMENT REPRESENTATION

i. Triangular Plate (Ident. No. 27)

The triangular plate element is recommended for use as the basic building block for most doubly curved shells when performing an elastic stability analysis. Additionally, it is useful in combination with the quadrilateral plate element (Ident. No. 28) for dealing with irregular geometries of membrane, plate and shell structures when performing buckling analyses. The triangular plate element is developed in detail in References 4 and 15 and is shown in Figure II-24.

The shape of the general triangular plate is defined by the coordinates of the three corner points. It is a zero curvature element. The plane of the element is determined by its three corner point coordinates.

Membrane and flexure action are uncoupled for this element. Optional generation of either or both of the representations is controlled by the provision of associated effective thicknesses. The distinct membrane and flexure thicknesses are assumed constant over the plane of the element.

Three corner points participate in establishing continuous connection of the triangular plate element with adjacent elements.

The triangular plate element, is written to accommodate anisotropy of mechanical and physical properties. Temperature referenced material properties, selected from the materials library, are assumed constant over the element.

A linear generalized Hooke's law is employed for the equations of state. The conventional plane stress option is provided for this element.

The element formulation is discretized by the construction of mode shapes. Membrane displacements within the element are approximated by linear mode shapes leading to constant membrane stress behavior within the element. Transverse displacement is represented by cubic polynomials.

Element stresses for the triangular plate are predicted at the center of the element. Inplane and normal direct, shear and bending stress results are included. The display of stresses implies a set of reference axes. These axes are data specified.

The following element matrices are provided for the Triangular Plate Element in the MAGIC System.

Stiffness
Stress
Thermal Load
Incremental Stiffness

A constant prestrain load vector is included in this element representation to accommodate thermal loading. The Grid Point Temperature Data Form (Figure II-7) is provided to input node point temperatures if thermal loading is present. For mid-plane (membrane) variations in thermal loading, the temperature input correspond to the temperatures designated T_1, on the Grid Point Temperature Data Form. These temperatures are input in Columns 13-22 of that form.

For flexural action, the gradient through the thickness is assumed constant. If temperature gradients through the thickness are present, the value of the gradient at each grid point is entered in the location set aside for the quantity, T_2 (Cols. 23-32) on the Grid Point Temperature Data Form. Thermal moments which arise from the gradients are then automatically defined by the System by prorating the distributed edge moments to the corners.

In the performance of elastic stability analyses using this element, the set of abstraction instructions as outined in Section II.g.4 of this volume should be utilized. Consistent "initial stress" incremental stiffness matrices are generated using the membrane stress results (σ_x, σ_y, σ_{xy}) from the triangular element in conjunction with the assumed transverse-displacement functions of the element, i.e.,

$$U = 1/2 \iint \left[N_x \left(\frac{\partial w}{\partial x}\right)^2 + N_y \left(\frac{\partial w}{\partial y}\right)^2 + 2N_{xy} \left(\frac{\partial w}{\partial x} \frac{\partial w}{\partial y}\right)\right] \partial x \, \partial y$$

The Element Control Data which is required for the Triangular Plate Element is as follows: (See Figure II-13)

<u>Element Number - (Cols. 7-10)</u>

Refer to Element Control Section

<u>Plug Number - (Cols. 11-12)</u>

The Triangular Plate Element is identified as Number 27.

<u>Material Number - (Cols. 13-18)</u>

Refer to Element Control Section

<u>Temperature Interpolate Option - (Col. 19)</u>

If the User exercises this option by <u>not</u> making an entry in Column 19, the program will <u>average</u> the three node point temperatures of the element and use this average temperature when establishing material properties from the material tape. If the User wishes to employ a specified number of node points, n, in

the averaging process ($1 < n < 3$) then this number is entered in Column 19 and the first n node points entered in Columns 36-71 will be used for the averaging process. If a '1' is entered in this location, the program will use the Material Temperature entered in Columns 20-27 when establishing material properties from the material tape.

Material Temperature - (Cols. 20-27)

Refer to Element Control Section

Repeat Element Matrices - (Col. 28)

Refer to Element Control Section

Element Input - (Col. 29)

The Triangular Plate Element always requires Element Input; therefore, an "X" is always placed in Column 29 when a triangular plate element is employed.

The following Element Input is required when using the Triangular Plate Element (Refer to the Element Input Section). From the Element Input Data Form it is seen that the Element Input Locations are labeled A, B, C, D, E, F, with each item contained in a ten column field.

Location A - (Cols. 13-22)

Membrane Thickness - (t_m)

For the Triangular Plate Element, both membrane and flexural action are represented. Optional generation of either or both representations is controlled by the provision of associated membrane and flexure thicknesses.

Location B - (Cols. 23-32)

Flexural Thickness - (t_f)

If the User desires to do a flexure problem, the effective flexure thickness must be entered. Omission of this thickness degenerates the problem into one of pure membrane behavior. Since flexure and membrane behavior are uncoupled both can be run consecutively if desired. In performing an elastic stability (buckling) analyses both the membrane and flexure thickness are needed.

The above is the Element Input required for the Triangular Plate Element. Returning to the Element Control Data Section, the list of data items continues as follows:

Interpolated Input Print - (Col. 30)

Refer to Element Control Section

Element Matrix Print - (Col. 31)

Refer to Element Control Section

Full Print - (Col. 32)

Refer to Element Control Section

Number of Input Nodes-(Cols. 33-34)

The Triangular Plate Element is always defined by 3 input nodes.

Pressure Suppression Option - (Col. 35)

Refer to Element Control Section

Node Points - (Cols. 36-71)

The Triangular Plate Element is defined by 3 node points. Note that the first two node points called out for the element determine the positive local "X" axis for stress output with the local "Y" axes at right angles pointing in the direction of the third node point.

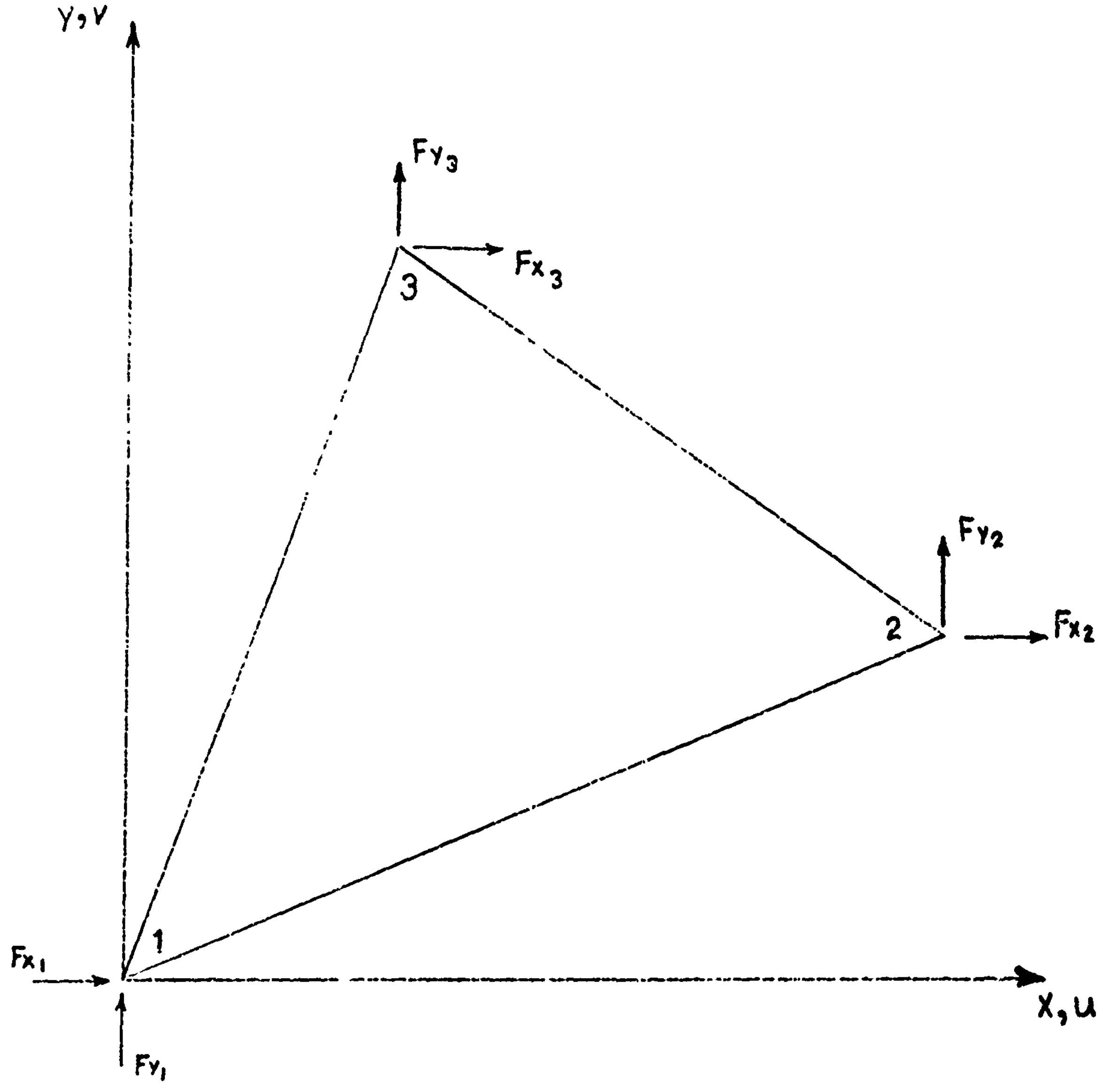


FIGURE II-24 TRIANGULAR PLATE ELEMENT REPRESENTATION

j. Incremental Frame (Ident. No. 13)

The formulation of the "incremental frame element" which has been incorporated into the MAGIC II System is essentially identical to the Frame Element (Ident. No. 11) described in Section II.16.a of this Manual (Pages 75-80). The representation for this element is developed in detail in Reference 8, and is shown in Figure II-15.

All element matrices available to Element Id. No. 11, are available to this element as well, i.e., Stiffness, Stress, Distributed Loading, Axial Thermal Load and Consistent Mass.

The addition of this element is primarily intended to serve the purpose of providing a companion frame element to the quadrilateral and triangular plate elements (Idents. No's. 28 and 27) which have been added to MAGIC II.

The use of this element in conjunction with the newly added quadrilateral and triangular plate elements provides a powerful capability for linear eigenvalue stability analyses of stiffened shell structures.

The incremental stiffness matrix employed for this element is derived in detail in Volume I: The Engineer's Manual, Section III.E.II (Reference 4).

All input data required for this element is identical to that required for the original Frame Element (Ident. No. 11). Therefore, in the interest of conciseness, the reader is referred to pages 75 thru 80 of this document for detailed element input description.

17. Check Or End Section (Figure II-22)

The labeled input data form provided for the Check or End Section is shown in Figure II-25.

A program option is provided to conduct a read and write of input data with execution suppressed. Output from the data read and write option includes the material properties derived from the materials library as well as tables completed by MODAL specification of data. It is recommended that this feature be used routinely to minimize execution against incorrect problem specifications. If the User desires to use the CHECK option, he simply scratches out the END designation which appears on the input data form. The keypunch operator will then punch the word CHECK in columns 1-5.

If the User does not want to exercise the CHECK option but wishes to execute the problem, he simply scratches out the CHECK designation which appears on the form. The keypunch operator will then punch the word END in columns 1-3.

MAGIC STRUCTURAL ANALYSIS SYSTEM

INPUT DATA FORMAT

CHECK OR END CARD

C	H	E	C	K	(/)
1	2	3	4	5	

E	N	D	(/)
1	2	3	

FIGURE II-25 CHECK OR END DATA FORM

SECTION III

INPUT AND OUTPUT OF THE MAGIC SYSTEM

A. GENERAL DESCRIPTION

In this section, the proper interpretation of the input supplied to the MAGIC System and the output supplied by the MAGIC System will be provided by reference to specific example problems. These examples will utilize the finite element representations which make up the element library of the MAGIC System.

B. THREE ELEMENT PORTAL FRAME

A three element portal frame is shown in Figure III-B.1, along with its loading, dimensions and pertinent material properties. The preprinted input data forms associated with this frame are displayed in Figures III-B.2 thru III-B.10.

In Figure III-B.6 (Boundary Condition Section) it is instructive to note the use of the MODAL and Repeat options. There are 2 exceptions to the MODAL Card (Grid points 2 and 3). Grid point 3 has exactly the same boundary conditions as Grid point 2, therefore the Repeat Option is employed by placing an 'X' in Column 12 opposite the entry for Grid Point Number 3. Note that the 2 exceptions to the MODAL card are called out on the System Control Information Data Form (Figure III-B.4).

In Figure III-B.7 (External Loads Section) the following information is evident.

(1) One load condition is input.

(2) The External Applied Load Scalar equals 0.0.

(3) Grid point number 2 is loaded with a load in the X direction equal to 550.0. It should be noted that the entry corresponding to External Moments is also filled in even though there are no external moments applied to the system. This is done because the Frame Element requires two external load cards per grid point.

In Figure III-B.9 (Element Input) it is noted that only the MODAL entry is used. This means that all of the Frame Elements used in this analysis have identical Element Input as follows:

Location A - Cross Sectional Area (A) = 18.0 in^2

Location B - Area Moment of Inertia (I_{zz}) = 13.5 in^4

Location C - Area Moment of Inertia (I_{yy}) = 13.5 in^4

Location D - Torsional Moment of Inertia (J) = 27.0 in^4

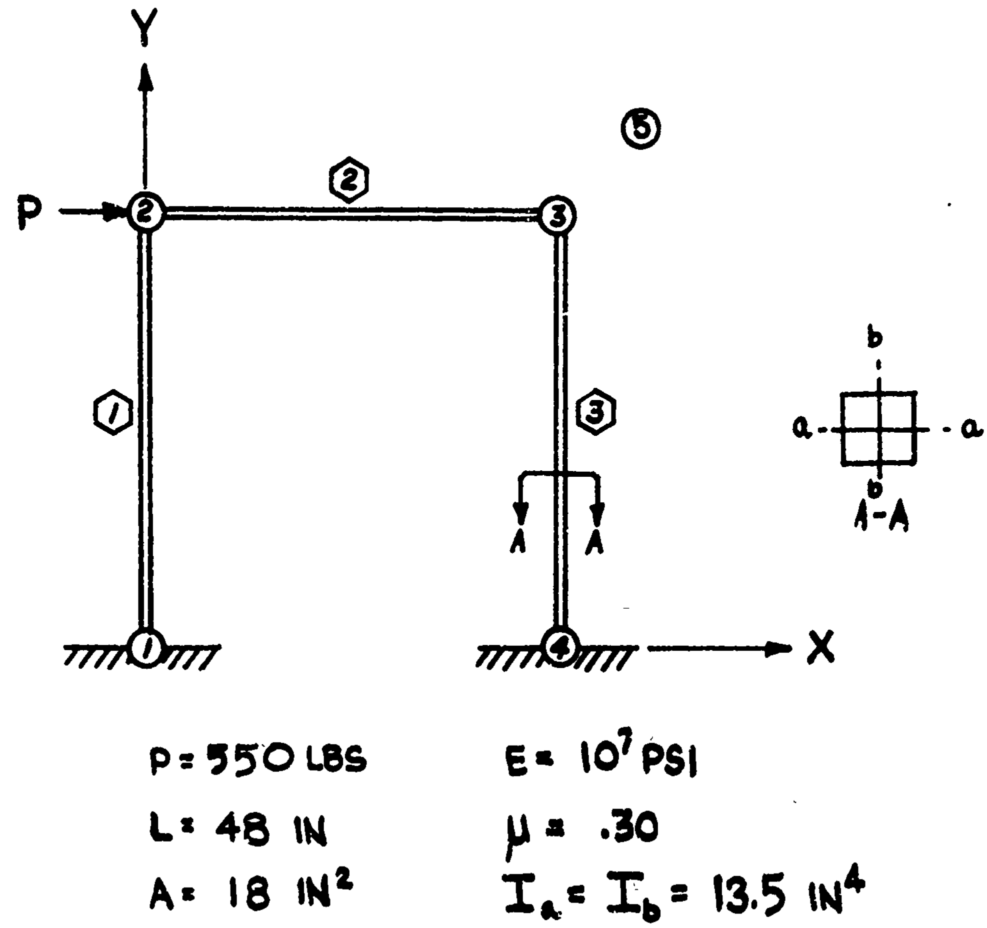


FIGURE III-B.1 - Idealized Three Element Portal Frame

BAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

REPORT (/)

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

1 2 3 4 5 6

TITLE (/)

7 8 9

13 (/) NUMBER OF TITLE CARDS

THREE ELEMENT PORTAL FRAME SUBJECTED TO A HORIZONTAL LOAD (/)

THREE FRAME ELEMENTS USED IN THE IDEALIZATION (/)

REFERENCE- H.C. MARTIN MATRIX METHODS OF STRUCTURAL ANALYSIS, PAGE 209 (/)

(/)

(/)

(/)

(/)

(/)

(/)

FIGURE III-B.2 TITLE INFORMATION, THREE ELEMENT PORTAL FRAME

SAC 1616-1

MATER (/)
1 2 3 4 5 6

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1 (/)
7 8 9
No. of Requests

MATERIAL TAPE INPUT

Request Number (7-9)	Material Number (10-15)	Lock Code (16-17)	Material Identification (18-41)	Isotropic (42)	Orthotropic (43)	Plastic Isotropic (44)	Plastic Orthotropic (45)	Add Plastic (46)	Delete Material (47)	Print Tape (48)	Print Mat'l. Table (49)	Print Mat'l. Summary (50)	Number of Mat'l. Pts. (51-52)	Number of Plastic Pts. (53-54)	Mass Density (55-64)	
1	12		TUALUMINUM - E=10E6, MU=0.3	X									1	0	0.00026	(/)

MATERIAL PROPERTIES TABLE

Temperature (13-22)	Direction	Youngs Moduli (23-32)	Direction	Poissons Ratios (33-42)	Direction	Coef. of Thermal Expansion (43-52)	Direction	Rigidity Moduli (53-62)	
0.0	E_x	10.0E06	ν_{xy}	0.3	α_x	12.5E-6	G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

FIGURE III-B.3 MATERIAL TAPE INPUT, THREE ELEMENT PORTAL FRAME

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

	1 2 3 4 5 6	S Y S T E M
1. Number of System Grid Points	1 2 3 4 5 6	5
2. Number of Input Grid Points	7 8 9 10 11 12	5
3. Number of Degrees of Freedom/Grid Point	13 14	6
4. Number of Load Conditions	15 16	1
5. Number of Initially Displaced Grid Points	17 18 19 20 21 22	
6. Number of Prescribed Displaced Grid Points	23 24 25 26 27 28	
7. Number of Grid Point Axes Transformation Systems	29 30	
8. Number of Elements	31 32 33 34 35 36	3
9. Number of Requests and/or Revisions of Material Tape.	37 38	1
10. Number of Input Boundary Condition Points	39 40 41 42 43 44	2
11. T_o For Structure (With Decimal Point)	45 46 47 48 49 50 51 52	0.0

FIGURE III-B.4 SYSTEM CONTROL INFORMATION, THREE ELEMENT PORTAL FRAME

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1 2 3 4 5 6

C O O R D (/)

GRIDPOINT COORDINATE

SYSTEM		
	COORD. INPUT	Ø
	RECTANGULAR	R/Δ
	CYLINDRICAL	C
	SPHERICAL	S

Δ = BLANK

$	Grid Point Number	DIRECTIONS X – R	DIRECTIONS Y – Θ	DIRECTIONS Z – Z	
	1	0.0	0.0	0.0	(/)
	2	0.0	48.0	0.0	(/)
	3	48.0	48.0	0.0	(/)
	4	48.0	0.0	0.0	(/)
	5	60.0	60.0	0.0	(/)

FIGURE III-B.5 GRIDPOINT COORDINATES, THREE ELEMENT PORTAL FRAME

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE	
	0 - No Displacement Allowed
	1 - Unknown Displacement
	2 - Known Displacement

1	2	3	4	5	6
B	O	U	N	D	

(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	θx	θy	θz	1	2	3	
13	14	15	16	17	18	19	20	21	
0	0	0	0	0	0				(/)

LISTED INPUT

Grid Point Number 7	8	9	10	11	Repeat 12	13	14	15	16	17	18	19	20	21	
				2		1	1	0	0	0	1				(/)
				3	X										(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)

FIGURE III-B.6 BOUNDARY CONDITIONS, THREE ELEMENT PORTAL FRAME

WAC 1627

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERNAL LOADS

Grid Pt Number	FORCE VALUES F_x	FORCE VALUES F_y	FORCE VALUES F_z	MOMENT VALUES M_x	MOMENT VALUES M_y	MOMENT VALUES M_z	GENERALIZED VALUES 1	GENERALIZED VALUES 2	GENERALIZED VALUES 3
2	551.0	0.0	.0	0.0	0.0	0.0			

FIGURE III-2.7 EXTERNAL LOADS, THREE ELEMENT PORTAL FRAME

DAC 1628

E	L	E	M		
1	2	3	4	5	6

(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM — INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER (7–10)	PLUG NO. (11–12)	MATERIAL NUMBER (13–18)	Interpolate Option (19)	MATERIAL TEMPERATURE (20–27)	Repeat Elem. Matrices (28)	Elem. Input (29)	PRINT Print (30)	PRINT Elem. Mat. (31)	PRINT Full (32)	Number of Input Nodes (33–34)	Suppress Pressures (35)	NODE POINTS 1 (36–38)	2 (39–41)	3 (42–44)	4 (45–47)	5 (48–50)	6 (51–53)	7 (54–56)	8 (57–59)	9 (60–62)	10 (63–65)	11 (66–68)	12 (69–71)
1	11					X			X	3		1	2	5									
2	11					X				3		2	3	5									
3	11					X				3		3	4	5									

FIGURE III-B.8 ELEMENT CONTROL DATA, THREE ELEMENT PORTAL FRAME

BAC 1(29-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT INPUT

E	X	T	E	R	N	(/)
1	2	3	4	5	6	

1 2 3 4 5 6	A (13–22)	B (23–32)	C (33–42)	D (43–52)	E (53–62)	F (63–72)
MODAL	18.0	13.5	13.5	27.0		

Element Number (7–11)	Repeat (12)	A (13–22)	B (23–32)	C (33–42)	D (43–52)	E (53–62)	F (63–72)	
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)

FIGURE III-B.9 ELEMENT INPUT, THREE ELEMENT PORTAL FRAME

MAGIC STRUCTURAL ANALYSIS SYSTEM

INPUT DATA FORMAT

CHECK OR END CARD

C	H	E	C	K	(/)
1	2	3	4	5	

E	N	D	(/)
1	2	3	

Figure III-B.10 End Card, Three Element Portal Frame

The output supplied by the MAGIC System for the three element portal frame is as follows.

Figure III-B.11 shows the matrix abstraction instructions associated with this particular problem. A complete discussion of these abstraction instructions is provided in Section II of this report. Figures III-B.12 thru III-B.14 display the output from the Structural System Monitor. These figures record the input data pertinent to the problem being solved.

Figure III-B 13 displays the coordinate and boundary condition information for this problem. In the Boundary Condition Information Section of the figure, zeros ('0') represents degrees of freedom that are fixed and ones ('1') represent degrees of freedom that have unknown values of displacement. The last column in the section represents the cumulative degree of freedom total.

The finite element information is also shown in Figure III-B.13. Under the section titled External Input, the first entry printed is the cross-sectional area of Element Number 1 which is equal to 18.0. The second and third entries printed are equal to the moments of inertia Izz and Iyy respectively with numerical values equalling 13.50. The fourth value printed is the Torsional Moment of Inertia, J, which in this case equals 27.00.

Figure III-B.14 displays the External Load Column for this problem. The 30 x 1 vector shown in the figure is the total unreduced transformed external load column which is read row-wise. The ordering is consistent with that of the boundary condition information shown in Figure III-B.13. Note that the external load of 550.0 is applied at node point Number 2 in the positive Global X direction.

MAGIC System output of final results is displayed in Figures III-B.15 thru III-B.22. Figure III-B.15 shows the reduced stiffness matrix for this problem. It is to be noted that only non-zero terms of the stiffness matrix are displayed. The stiffness matrix is presented row-wise and its ordering is consistent with that of the boundary conditions shown in Figure III-B.13. For this case, the ordering of the displacement vector is as follows:

$$\{q\}^T = \lfloor u_2, v_2, \theta_{z2}, u_3, v_3, \theta_{z3} \rfloor$$

The Externally Applied Load Vector (GPRINT OF MATRIX LOADS) is presented in Figure III-B.16. From the figure, it is observed that the force value presented corresponds to a force (Fx) in the Global X direction at node point 2 numerically equal to 550.0.

The portal frame displacements resulting from the Force (Fx) of 550.0 at node point 2 are also shown in Figure III-B.16. It is noted that the displacements (U, V, W, THETAX, THETAY, THETAZ) are output corresponding to node point number and are referenced to the global axis unless otherwise specified.

The final items of information contained in Figure III-B.16 are the Reactions for the problem in question. It is noted that the Reactions (F_X, F_Y, F_Z, M_X, M_Y, M_Z) are output corresponding to node point number and are referenced to the global axis unless otherwise specified.

Stresses for the three element portal frame are given in Figures III-B.17 thru III-B.19. Stresses are referenced to element coordinates, and for the frame element, description of stress behavior is accepted as the definition of the twelve forces (F_X, F_Y, F_Z, M_X, M_Y, M_Z) acting at the two grid point connections. (See Figure III-B.1 for Element Numbering.) In Figure III-B.17, Stresses (Element Forces Referenced To Element Axes) for Element No. 1 are presented. Stress Points 1 and 2 correspond to Element Grid Points 1 and 2 for this particular element. (Note that the third grid point, in this case grid point 5, is only used to define the plane of the element., Figures III-B.18 and III-B.19 present stresses for element numbers 2 and 3 respectively.

Element forces for the three element portal frame are displayed in Figures III-B.20 thru III-B.22. These forces are defined with respect to the Global Coordinate System.

Figure III-B.20 presents the element forces (F_X, F_Y, F_Z, M_X, M_Y, M_Z) for Element No. 1. Points 1, 2 and 3 correspond to Element Grid Points 1, 2, and 5 respectively for this particular element. Note that the third grid point, in this case grid point 5, is only used to define the plane of the element and therefore there are no element forces evaluated at this particular point, i.e., Point 3 in Figure III-B.20. Figures III-B.21 and III-B.22 present forces for element numbers 2 and 3 respectively.

```
                MAGIC ABSTRACTION INSTRUCTION LISTING              PAGE   1

     TEST MAGIC

INSTRUCTION   STATICS

        C
        C---- STATICS AGENDUM WITHOUT PRESCRIBED DISPLACEMENTS
        C
        C        * * * * * * * * * * * * * * * * * * * * * *
        C
        C        STATICS INSTRUCTION SEQUENCE
        C
        C        * * * * * * * * * * * * * * * * * * * * * *
        C
        C        GENERATE ELEMENT MATRICES
        C
  1            ,MLIB,,XLD,TR,  ,KEL,FTEL,SEL,STEL,,,SC,EM,  =,,     ,.USER04.
        C
        C
        C        FORM (1 X 1) UNIT AND (1 X 1) NULL MATRICES
        C        DETERMINE PRINT FORMAT FOR TYPE OF ELEMENTS USED
        C
  2            I1 = SC.IDENTC.
  3            I3 = I1.NULL.SC
  4            CIFF = I1.SMULT.SC(10,1)
        C
        C        ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LOADS
        C
  5            KELA = EM .ASSEM. SC,(10)
  6            FTELA = EM .ASSEM .SC,(40)
  7            LSCALE,LOADS = XLD .DEJOIN.(1,1)
        C
        C        REDUCE STIFFNESS MATRIX AND PRINT
        C
  8            KO,KNO = KELA .DEJOIN.( SC(5,1),1)
  9            KCO,STIFF = KNC.DEJOIN.( SC(5,1),0)
 10            PRINT(FORCE,DISP,,) STIFF
        C
        C        FORM REDUCED TOTAL LOAD COLUMN
        C
        C        MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR
 11            FTELS = FTELA.MULT.LSCALE
        C        TRANSFORM EXTERNAL LOADS TO 0-1-2 ASSEMBLED SYSTEM
 12            LOADO = TR.MULT.LOADS
        C        FORM TOTAL LOAD COLUMNS
 13            TLOAD = FTELS.ADD.LOADO
 14            TL,TLOADR = TLOAD.DEJOIN.( SC(5,1),1)
        C
        C        SOLVE FOR DISPLACEMENTS
        C
 15            XX = STIFF.SEQEL.TLOADR
 16            TRO,TR12 = TR.DEJOIN.(SC(5,1),1)
 17            X = TR12.TMULT.XX
 18            XO = TR.MULT.X
        C
```

FIGURE III.A.11 FORMAT ABSTRACTION INSTRUCTION LISTING

TEST MAGIC

```
      C          CALCULATE REACTIONS AND INVERSE CHECK
      C
19          REACTS = KELA.MULT.XO
20          REACTP= REACTS.SUBT.TLOAD
21          IF (DIFF.NULL.) GO TO 10
      C
      C          PRINT ELEMENT APPLIED LOADS, EXTERNAL LOADS, DISPLACEMENTS,
      C            REACTIONS AND INVERSE CHECK IN ENGINEERING FORMAT
      C
      C          ELEMENTS HAVE 1 OR 2 DEGREES OF FREEDOM
      C
22          GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR )FTELA
23          GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,    )LOADS
24          GPRINT( 2,,,U.V.W.THETAX.THETAY.THETAZ,SC,)X
25          GPRINT(1,,,FX.FY.FZ.MX.MY.MZ,SC,TR )REACTP
26          IF (I3.NULL.) GO TO 600
      C
      C          ELEMENTS HAVE 3 DEGREES OF FREEDOM
      C
27      10  GPRINT(4,,,FR.O.FZ.O.MBETA.O.F1.O.F3,SC,TR )FTELA
28          GPRINT(4,,,FR.O.FZ.O.MBETA.O.F1.O.F3,SC,    )LOADS
29          GPRINT(2,,,U.O.W.O.THETAY.O.W*.O.W**,SC, )X
30          GPRINT(1,,,FR.O.FZ.O.MBETA.O.F1.O.F3,SC,TR )REACTP
      C
      C          GENERATE STRESSES AND FORCES
      C
31     600  STRESP=EM,XO .STRESS.(4,)
32          FORCEP=EM,XO .FORCE.(4,)
```

FIGURE III-B.11 FORMAT ABSTRACTION INSTRUCTION LISTING (CONT)

```
THREE ELEMENT PORTAL FRAME SUBJECTED TO A HORIZONTAL LOAD

THREE FRAME ELEMENTS USED IN THE IDEALIZATION

REFERENCE- H.C.MARTIN MATRIX METHODS OF STR. ANALYSIS PAGE 209

                    REVISIONS OF MATERIAL TAPE

                 ASTERISK (*) PRECEEDING MATERIAL
                 IDENTIFICATION INDICATES THAT INPUT
                 ERROR RETURNS WILL NOT RESULT IN
                      TERMINATION OF EXECUTION

****************************************************************************************

REVISION
  MATERIAL NUMBER      12                                INPUT CODE   1
  MATERIAL IDENTIFICATION   ALUMINUM
    NUMBER OF MATERIAL PROPERTY POINTS. . . . .  1
    NUMBER OF PLASTIC PROPERTY POINTS . . . . . -0
    MASS DENSITY. . . . . . . . . . . . . . . . -0.

  MATERIAL PROPERTIES
                                                                   POISSON'S RATIOS
                       YOUNG'S MODULI
                                                                     DIRECTIONS
                         DIRECTIONS
TEMPERATURE                                                 XY           YZ           ZX
                   XX           YY           ZZ       0.300000E 00 0.300000E 00 0.300000E 00
    0.        0.100000E 08 0.100000E 08 0.100000E 08
                                                                    RIGIDITY MODULI
                 THERMAL EXPANSION COEFFICIENTS
                                                                      DIRECTIONS
                         DIRECTIONS
TEMPERATURE                                                 XY           YZ           ZX
                   XX           YY           ZZ       0.384615E 07 0.384615E 07 0.384615E 07
    0.        0.125000E-04 0.125000E-04 0.125000E-04

****************************************************************************************
```

FIGURE III-B.12 TITLE AND MATERIAL DATA OUTPUT, THREE ELEMENT PORTAL FRAME

5 REF. POINTS

NO. DIRECTIONS = 3 NO. DEGREES OF FREEDOM = 2

GRIDPOINT DATA
(IN RECTANGULAR COORDINATES)

POINT	X	Y	Z	TEMPERATURES	PRESSURES
1	0.0	0.0	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
2	0.0	0.480000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
3	0.480000000E 02	0.480000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
4	0.480000000E 02	0.0	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
5	0.600000000E 02	0.600000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0

BOUNDARY CONDITION INFORMATION

NODES	DEGREES OF FREEDOM						NO. OF ONES	NO. OF TWOS
1	0	0	0	0	0	0	0	0
2	1	1	0	0	0	1	3	0
3	1	1	0	0	0	1	6	0
4	0	0	0	0	0	0	6	0
5	0	0	0	0	0	0	6	0

FIGURE III-B.13 GRIDPOINT DATA, BOUNDARY CONDITION [illegible]
OUTPUT, THREE ELEMENT PORTAL FRAME

```
                         TOTAL NO. ELEMENTS =        3

                                               ---------GRID POINTS---------   EXTRA GRID PTS   ------SECTION PROPERTIES------
ELEM TYPE  MAT.NO. CODE   TEMP.    PRNT  NO.
  1  11       12    0   0.0          2    3    1  2  5

MATERIAL NUMBER. . . . . . . .    12
    MATERIAL IDENTIFICATION. . . .  ALUMINUM
    ANALYSIS CAPABILITY. . . . . .  ISOTROPIC
    INPUT PRINT CODE . . . . . . .  1
    ELEMENT PRINT CODE . . . . . . -1


INTERPOLATED MATERIAL PROPERTIES
    TEMPERATURE -           0.0
    YOUNG'S MODULI        0.10000000E 08     0.10000000E 08     0.10000000E 08
    POISSON'S RATIO       0.29999995E 00     0.29999995E 00     0.29999995E 00
    TH. EXP. COEF.        0.12500000E-04     0.12500000E-04     0.12500000E-04
    RIGIDITY MODULI       0.38461560E 07     0.38461560E 07     0.38461560E 07

INTERPOLATED PLASTIC PROPERTIES
    NONE

PRE-STRAIN INPUT
    NONE

PRE-STRESS INPUT
    NONE

EXTERNAL INPUT                                                                     0.0
         0.18000000E 02     0.13500000E 02     0.13500000E 02     0.27000000E 02

                                                                                 ------SECTION PROPERTIES------
                                               ---------GRID POINTS---------   EXTRA GRID PTS   0.1800E 02   0.1350E 02   0.1350E 02
ELEM TYPE  MAT.NO. CODE   TEMP.    PRNT  NO.                                   0.2700E 02   0.0
  2  11       12    0   0.0          0    3    2  3  5                         0.1800E 02   0.1350E 02   0.1350E 02
                                                                               0.2700E 02   0.0
  3  11       12    0   0.0          0    3    3  4  5
```

FIGURE III-B.13 GRIDPOINT DATA, BOUNDARY CONDITION AND FINITE ELEMENT DESCRIPTION OUTPUT, THREE ELEMENT PORTAL FRAME (CONTINUED)

```
                              EXTERNAL LOAD CONDITIONS   1

        LOAD NO.   1
          NUMBER OF LOADED NODES     1         ELEMENT LOAD SCALAR =  0.
      2  0.55000E 03  0.          0.          0.          0.          0.

                         TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN

                                       30 X 1

   0.               0.            0.            0.            0.            0.
   0.55000000E 03   0.            0.            0.            0.            0.
   0.               0.            0.            0.            0.            0.
   0.               0.            0.            0.            0.            0.
   0.               0.            0.            0.            0.            0.

                              T-ZERO FOR STRUCTURE =  0.
```

FIGURE III-B.14 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, THREE ELEMENT PORTAL FRAME

MATRIX STIFF PAGE 1

CUTOFF = 0. SIZE 6 BY 6

	FORCE Row	Col.	K_{ij}	FORCE Col.	K_{ij}	FORCE Col.	K_{ij}	FORCE Col.	K_{ij}	FORCE Col.	K_{ij}
DISP.	1	1	0.376465E 07	3	0.351562E 06	4	-0.375000E 07				
DISP.	2	2	0.376465E 07	3	0.351562E 06	5	-0.146484E 05	6	0.351562E 06		
DISP.	3	1	0.351562E 06	2	0.351562E 06	3	0.225000E 08	5	-0.351562E 06	6	0.562500E 07
DISP.	4	1	-0.375000E 07	4	0.376465E 07	6	0.351562E 06				
DISP.	5	2	-0.146484E 05	3	-0.351562E 06	5	0.376465E 07	6	-0.351562E 06		
DISP.	6	2	0.351562E 06	3	0.562500E 07	4	0.351562E 06	5	-0.351562E 06	6	0.225000E 08

FIGURE III-B.15 REDUCED STIFFNESS MATRIX OUTPUT, THREE ELEMENT PORTAL FRAME

GPRINT OF MATRIX LOADS (SET 1)

ROW	FX	FY	FZ	MX	MY	MZ
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.55000000E 03	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0

DISPLACEMENT MATRIX FOR LOAD CONDITION 1

30 X 1

ROW	U	V	W	THETAX	THETAY	THETAZ
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.26910093E-01	0.62788444E-04	0.0	0.0	0.0	-0.33824937E-03
3	0.26836831E-01	-0.62788444E-04	0.0	0.0	0.0	-0.33672620E-03
4	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0

REACTIONS AND INVERSE CHECK FOR LOAD CONDITION 1

ROW	FX	FY	FZ	MX	MY	MZ
1	-0.27527535E 03	-0.23545653E 03	0.0	0.0	0.0	0.75579531E 04
2	-0.62500000E-01	-0.19836426E-03	0.0	0.0	0.0	0.48828125E-02
3	-0.56304932E-02	0.33569336E-03	0.0	0.0	0.0	-0.78125000E-02
4	-0.27473730E 03	0.23545653E 03	0.0	0.0	0.0	0.75407187E 04
5	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE III-B.16 LOAD, DISPLACEMENT AND REACTION OUTPUT, THREE ELEMENT PORTAL FRAME

STRESSES FOR THE FRAME ELEMENT

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	11	1 2 5

APPARENT ELEMENT STRESSES

STRESS POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	-0.23545653E 03	-0.2752756 E 03	0.0	0.0	0.0	-0.75579609E 04
2	0.23545653E 03	0.27527563E 03	0.0	0.0	0.0	-0.56552773E 04

ELEMENT APPLIED STRESSES

STRESS POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	-0.23545653E 03	-0.27527563E 03	0.0	0.0	0.0	-0.75579609E 04
2	0.23545653E 03	0.27527563E 03	0.0	0.0	0.0	-0.56552773E 04

FIGURE III-B.17 STRESS OUTPUT, ELEMENT NO. 1, THREE ELEMENT PORTAL FRAME

STRESSES FOR THE FRAME ELEMENT

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	2	11	2 3 5

APPARENT ELEMENT STRESSES

STRESS POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.27468750E 03	-0.23545688E 03	0.0	0.0	0.0	-0.56552500E 04
2	-0.27468750E 03	0.23545688E 03	0.0	0.0	0.0	-0.56466719E 04

ELEMENT APPLIED STRESSES

STRESS POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.27468750E 03	-0.23545688E 03	0.0	0.0	0.0	-0.56552500E 04
2	-0.27468750E 03	0.23545688E 03	0.0	0.0	0.0	-0.56466719E 04

FIGURE III-B.18 STRESS OUTPUT, ELEMENT NO. 2, THREE ELEMENT PORTAL FRAME

STRESSES FOR THE FRAME ELEMENT

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	3	11	3 4 5

APPARENT ELEMENT STRESSES

STRESS POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.23545653E 03	0.27473755E 03	0.0	0.0	0.0	0.56466797E 04
2	-0.23545653E 03	-0.27473755E 03	0.0	0.0	0.0	0.75407344E 04

ELEMENT APPLIED STRESSES

STRESS POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.23545653E 03	0.27473755E 03	0.0	0.0	0.0	0.56466797E 04
2	-0.23545653E 03	-0.27473755E 03	0.0	0.0	0.0	0.75407344E 04

FIGURE III-B.19 STRESS OUTPUT, ELEMENT NO. 3, THREE ELEMENT PORTAL FRAME

F O R C E S   F O R   T H E   F R A M E   E L E M E N T

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	11	1 2 5

APPARENT ELEMENT FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	-0.27527539E 03	-0.235454653E 03	0.0	0.0	0.0	0.755799531E 04
2	0.27527539E 03	0.235454653E 03	0.0	0.0	0.0	0.565525578E 04
3	0.0	0.0	0.0	0.0	0.0	0.0

ELEMENT APPLIED FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(PZ)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	-0.27527539E 03	-0.235454653E 03	0.0	0.0	0.0	0.755799531E 04
2	0.27527539E 03	0.235454653E 03	0.0	0.0	0.0	0.565525578E 04
3	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE III-B.20 FORCE OUTPUT, ELEMENT NO. 1, THREE ELEMENT PORTAL FRAME

F O R C E S   F O R   T H E   F R A M E   E L E M E N T

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	2	11	2 3 5

APPARENT ELEMENT FORCES

POINT	FORCES AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.27468750E 03	-0.23545668E 03	0.0	0.0	0.0	-0.56552500E 04
2	-0.27468750E 03	0.23545683E 03	0.0	0.0	0.0	-0.56466641E 04
3	0.0	0.0	0.0	0.0	0.0	0.0

ELEMENT APPLIED FORCES

POINT	FORCES AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT FORCES

POINT	FORCES AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.27468750E 03	-0.23545668E 03	0.0	0.0	0.0	-0.56552500E 04
2	-0.27468750E 03	0.23545683E 03	0.0	0.0	0.0	-0.56466641E 04
3	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE III-B.21 FORCE OUTPUT, ELEMENT NO. 2, THREE ELEMENT PORTAL FRAME

NOT REPRODUCIBLE

F O R C E S F O R T H E F R A M E E L E M E N T

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	3	11	3 4 5

APPARENT ELEMENT FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.27473730E 03	-0.235456653E 03	0.0	0.0	0.0	0.564666641E 04
2	-0.27473730E 03	0.235456653E 03	0.0	0.0	0.0	0.754071187E 04
3	0.0	0.0	0.0	0.0	0.0	0.0

ELEMENT APPLIED FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.27473730E 03	-0.235456653E 03	0.0	0.0	0.0	0.564666641E 04
2	-0.27473730E 03	0.235456653E 03	0.0	0.0	0.0	0.754071187E 04
3	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE III-B.22 FORCE OUTPUT, ELEMENT NO. 3, THREE ELEMENT PORTAL FRAME

C. CANTILEVER BEAM

A cantilever beam is shown in Figure III-C.1 along with its loading, dimensions and pertinent material properties. The beam is idealized using axial force members and a quadrilateral shear panel. The preprinted input data forms associated with this beam are displayed in Figures III-C.2 through III-C.10.

In Figure III-C.6 (Boundary Condition Section) it is interesting to note the use of the MODAL and Repeat options. There are two exceptions to the MODAL card (Grid Points 2 and 3). Grid Point 3 has exactly the same boundary conditions as Grid Point 2, therefore the Repeat option is employed by placing an 'X' in Column 12 opposite the entry for Grid Point 3. Note that the 2 exceptions to the MODAL card are called out on the System Control Information Data Form (Figure III-C.4).

In Figure III-C.7 (External Loads Section) Grid Points 3 and 4 have applied external loading. Note that there are 2 external load cards per grid point.

In Figure III-C.9 (Element Input) the MODAL card is used for Element Numbers 2 and 3. These are the Axial Force Members parallel to the X Axis. For Element Number 1, the Quadrilateral Shear Panel, the thickness of 0.0787 inches is entered in Location A. Finally for Element No. 4 the cross-sectional area of 0.10 sq. inches is entered. The area for Element No. 5 is repeated by simply placing an "X" in the repeat column opposite the entry for Element No. 5.

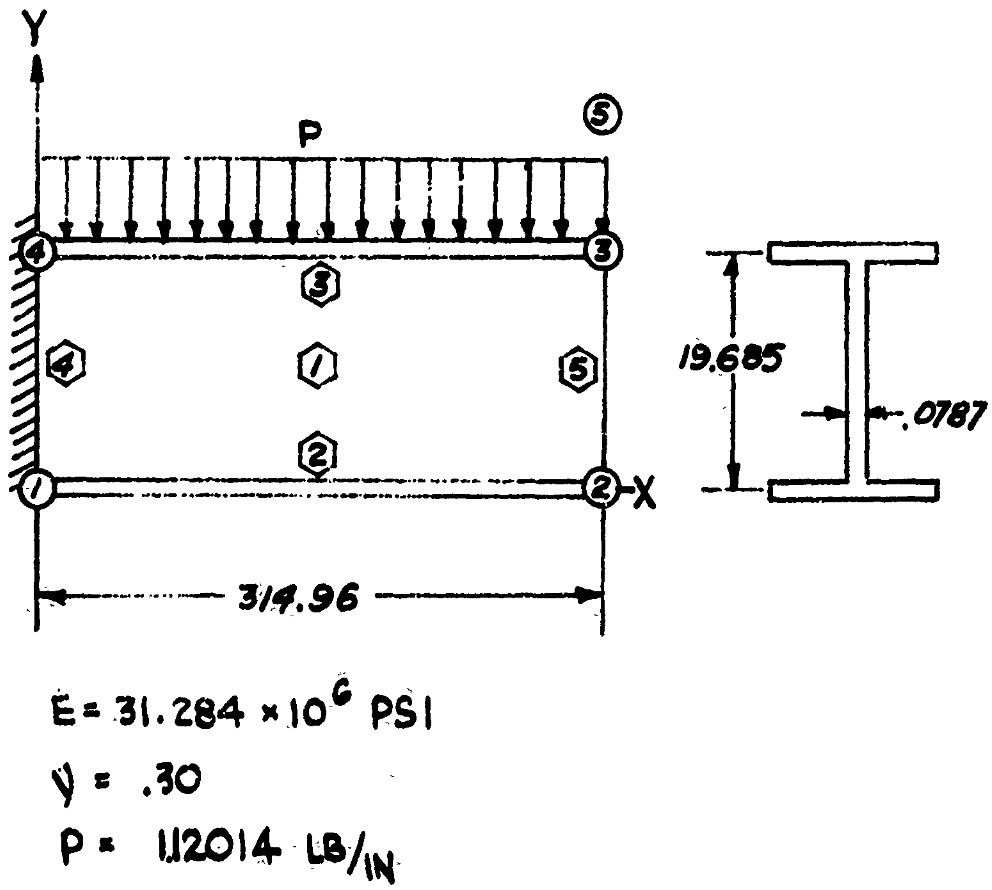


FIGURE III-C.1 - Idealized Cantilever Beam

BAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

REPORT (/)

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

1 2 3 4 5 6
TITLE (/)

7 8 9
15 (/) NUMBER OF TITLE CARDS

ØNE ELEMENT CANTILEVER BEAM IDEALIZED U$ING FØUR AXIAL FØRCE (/)

MEMBER$ AND ØNE QUADRILATERAL $HEAR PANEL REFERENCE: UPPER AND (/)

LØWER BØUND$ TØ $TRUCTURAL DEFØRMATIØN$ BY DUAL ANALYI IN (/)

FINITE ELEMENT$ G. $ANDER AND B. FRAEIJS DE VEUBEKE AFFDL TR 66 199 (/)

PAGE$ 112-118 (/)

(/)

(/)

(/)

(/)

FIGURE III-C.2 TITLE INFORMATION, CANTILEVER BEAM

BAC 1616-1

M	A	T	E	R		(/)
1	2	3	4	5	6	

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

		1	(/)
7	8	9	

No. of Requests

MATERIAL TAPE INPUT

Request Number	MATERIAL NUMBER	Lock Code	MATERIAL IDENTIFICATION	Isotropic	Orthotropic	Plastic Isotropic	Plastic Orthotropic	Add Plastic	Delete Material	Print Tape	Print Mat'l. Table	Print Mat'l. Summary	Number of Mat'l. Pts.	Number of Plastic Pts.	MASS DENSITY	
7 8 9	10 1 2 3 4 5	6 7	8 9 20 1 2 3 4 5 6 7 8 9 30 1 2 3 4 5 6 7 8 9 40 1	42	43	44	45	46	47	48	49	50	51 2	3 4	5 6 7 8 9 60 1 2 3 4	
1	99398	RH	E=3.13E7 MU=0.30	X									1			(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE	Direction	YOUNGS MODULI	Direction	POISSONS RATIOS	Direction	COEF. OF THERMAL EXPANSION	Direction	RIGIDITY MODULI	
13 4 5 6 7 8 9 20 1 2		23 4 5 6 7 8 9 30 1 2		33 4 5 6 7 8 9 40 1 2		43 4 5 6 7 8 9 50 1 2		53 4 5 6 7 8 9 60 1 2	
0.0	E_x	31.284 E6	ν_{xy}	0.30	α_x	12.5 E-6	G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

FIGURE III-C.3 MATERIAL TAPE INPUT, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

Item	Request	Columns	Entry
		1 2 3 4 5 6	S Y S T E M (/)
1.	Number of System Grid Points	1 2 3 4 5 6	5
2.	Number of Input Grid Points	7 8 9 10 11 12	5
3.	Number of Degrees of Freedom/Grid Point	13 14	6
4.	Number of Load Conditions	15 16	1
5.	Number of Initially Displaced Grid Points	17 18 19 20 21 22	
6.	Number of Prescribed Displaced Grid Points	23 24 25 26 27 28	
7.	Number of Grid Point Axes Transformation Systems	29 30	
8.	Number of Elements	31 32 33 34 35 36	5
9.	Number of Requests and/or Revisions of Material Tape.	37 38	1
10.	Number of Input Boundary Condition Points	39 40 41 42 43 44	2
11.	T_o For Structure (With Decimal Point)	45 46 47 48 49 50 51 52	0.0 (/)

FIGURE III-C.4 SYSTEM CONTROL INFORMATION, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6
C	O	O	R	D	

(/)

GRIDPOINT COORDINATE

COORD. INPUT	$
SYSTEM: RECTANGULAR	R/Δ
SYSTEM: CYLINDRICAL	C
SYSTEM: SPHERICAL	S

Δ = BLANK

$ (5–6)	Grid Point Number (7–12)	DIRECTIONS: X – R (13–22)	DIRECTIONS: Y – θ (23–32)	DIRECTIONS: Z – Z (33–42)	
	1	0.0	0.0	0.0	(/)
	2	314.960	0.0	0.0	(/)
	3	314.960	19.6063	0.0	(/)
	4	0.0	19.6063	0.0	(/)
	5	314.960	25.0	0.0	(/)

FIGURE III-C.5 GRIDPOINT COORDINATES, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE -	
	0 - No Displacement Allowed
	1 - Unknown Displacement
	2 - Known Displacement

1	2	3	4	5	6	
B	O	U	N	D		(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	θx	θy	θz	1	2	3	
13	14	15	16	17	18	19	20	21	
0	0	0	0	0	0				(/)

LISTED INPUT

Grid Point Number					Repeat	TRANSLATIONS			ROTATIONS			GENERALIZED			
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
				2		1	1	0	0	0	0				(/)
				3	X										(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)

FIGURE III.C.6 BOUNDARY CONDITIONS, CANTILEVER BEAM

SAL 1637

LOADS

LCOND 1 0.0

Condition Number

Transformation Code For Loads

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MODAL

EXTERNAL LOADS

Grid Pt. Number	FORCE VALUES F_x	FORCE VALUES F_y	FORCE VALUES F_z	MOMENT VALUES M_x	MOMENT VALUES M_y	MOMENT VALUES M_z	GENERALIZED VALUES 1	GENERALIZED VALUES 2	GENERALIZED VALUES 3
3	0.0	-176.57965	0.0	0.0	0.0	0.0			
4	0.0	-176.57965	0.0	0.0	0.0	0.0			

FIGURE III-C.7 EXTERNAL LOADS, CANTILEVER BEAMS

BAC 1028

ELEM
1 2 3 4 5 6

(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM INPUT DATA FORMAT

ELEMENT CONTROL DATA

Element Number (7–10)	Plug No. (11–12)	Material Number (13–18)	Interpolate Option (19)	Material Temperature (20–27)	Repeat Elem. Matrices (28)	Elem. Input (29)	Print: Print (30)	Print: Elem. Mat. (31)	Print: Full (32)	Number of Input Nodes (33–34)	Suppress Pressures (35)	Node Points 1 (36–38)	2 (39–41)	3 (42–44)	4 (45–47)	5 (48–50)	6 (51–53)	7 (54–56)	8 (57–59)	9 (60–62)	10 (63–65)	11 (66–68)	12 (69–71)
1	25	99398				X			X	4		1	2	3	4								
2	11	99398				X			X	3		1	2	5									
3	11	99398				X				3		3	4	5									
4	11	99398				X				3		1	4	5									
5	11	99398				X				3		2	3	5									

FIGURE III-C.8 ELEMENT CONTROL DATA, CANTILEVER BEAM

SAC 1629-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT INPUT

EXTERN (/)

1-6	A (13-22)	B (23-32)	C (33-42)	D (43-52)	E (53-62)	F (63-72)
MODAL	1.550					

Element Number (7-11)	Repeat (12)	A (13-22)	B (23-32)	C (33-42)	D (43-52)	E (53-62)	F (63-72)	
1		0.07870						(/)
4		0.10						(/)
5	X							(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)

FIGURE III-C.9 ELEMENT INPUT, CANTILEVER BEAM

MAGIC STRUCTURAL ANALYSIS SYSTEM

INPUT DATA FORMAT

CHECK OR END CARD

C	H	E	C	K	(/)
1	2	3	4	5	

E	N	D	(/)
1	2	3	

FIGURE III-C.10 END CARD, CANTILEVER BEAM

The output supplied by the MAGIC System for the cantilever beam is as follows:

Figures III-C.11 thru III-C.14 display the output from the Structural Systems Monitor. These figures display the input data pertinent to the particular problem being solved.

Referring to Figure III-C.1 it is seen that one shear panel and four axial force members are used in this idealization. Element Number 1 represents the shear panel while Elements 2, 3, 4, and 5 represent the axial force members. In Figure III-C.13, the external input for element number 1 is equal to 0.07870. This value represents the thickness of the quadrilateral shear panel being employed. For elements 2 and 3 the values of the external input are equal to 1.55 while for elements 4 and 5 the values are equal to 0.10. These values represent the cross-sectional area of the respective axial force members.

Figure III-C.14 displays the transformed external assembled (unreduced) load column for this problem. This vector is read row-wise and is consistent with the ordering of the displacements displayed in the Boundary Condition Section shown in Figure III-C.12. It is seen from this vector that an externally applied load of -176.40 is acting at node point 3 in the negative Y direction and a force of -176.40 is acting at node point 4 also in the negative Y direction.

Figure III-C.15 shows the assembled and reduced stiffness matrix for this problem. The stiffness matrix is presented row-wise and its ordering is consistent with that of the boundary conditions shown in Figure III-C.12. For this case, the ordering of the displacement vector is as follows:

$$\{q\}^T = \lfloor u_2, v_2, u_3, v_3 \rfloor$$

Figure III-C.16 displays External Load, Displacement and Reaction Information.

The Externally Applied Load Vector (GPRINT OF MATRIX LOADS) is shown first in Figure III-C.16. From the figure, it is observed that the force values presented correspond to forces, F_y, acting in the negative Global Y direction at node points 3 and 4. The magnitude of each force component is equal to -176.40 Note that at node point 4 the degree-of-freedom in which the applied force is acting is bounded out. (See Boundary Condition Information, Figure III-C.12.)

The displacements for this application are also shown in Figure III-C.16. It is noted that the Displacements (U, V, W, THETAX, THETAY, THETAZ) are output corresponding to node point number and are referenced to the global axis unless otherwise specified.

The final items of information contained in Figure III-C.16 are the Reactions, (F_X, F_Y, F_Z, M_X, M_Y, M_Z) which are output corresponding to node point number and are referenced to the global axis unless otherwise specified.

Stresses for ' e Quadrilateral Shear Panel are shown in Figure III-C.17. The quadrilateral shear panel is described by one constant shear stress value.

Stresses for the Frame Elements (Axial Force Members) are shown in Figures III-C.18 thru III-C.21. Description of stress behavior for the axial force member is accepted as the definition of the twelve forces (F_X, F_Y, F_Z, M_X, M_Y, M_Z) acting at the two grid point connections. (See Figure III-C.1 for Element Numbering.)

Element forces for this application are displayed in Figures III-C.22 thru III-C.26. These forces are defined with respect to the Global Coordinate System. Figure III-C.22 displays the element forces for the Quadrilateral Shear Panel Element. This element is defined by four node points and six forces are associated with each node point. For this application, force points 1, 2, 3, and 4 correspond to element grid points 1, 2, 3, and 4. Figures III-C.23 thru III-C.26 define the element forces for Element Numbers 2 thru 5 respectively. The interpretation of these forces is exactly the same as those in the previous example (Three Element Portal Frame, Figures III-B.20 thru III-B.22).

```
ONE ELEMENT CANTILEVER BEAM IDEALIZED USING FOUR AXIAL FORCE
MEMBERS AND ONE QUADRILATERAL SHEAR PANEL REFERENCE' UPPER AND
LOWER BOUNDS TO STRUCTURAL DEFORMATIONS BY DUAL ANALYSIS IN
FINITE ELEMENTS G.SANDER AND B.FRAEIJS DE VEVBEKE AFFDL TR 66 199
PAGES 112-118

                         REVISIONS OF MATERIAL TAPE

                      ASTERISK (*) PRECEEDING MATERIAL
                      IDENTIFICATION INDICATES THAT INPUT
                      ERROR RETURNS WILL NOT RESULT IN
                           TERMINATION OF EXECUTION

***************************************************************************

REVISION
  MATERIAL NUMBER  99398
  MATERIAL IDENTIFICATION   E=3.13E7 NU=0.30             INPUT CODE   1
    NUMBER OF MATERIAL PROPERTY POINTS. . . .  1
    NUMBER OF PLASTIC PROPERTY POINTS . . . . -0
    MASS DENSITY. . . . . . . . . . . . . . .-0.

  MATERIAL PROPERTIES

                   YOUNG'S MODULI                               POISSON'S RATIOS

                     DIRECTIONS                                    DIRECTIONS
TEMPERATURE
                XX              YY              ZZ              XY              YZ              ZX
    0.     0.312840E 08    0.312840E 08    0.312840E 08    0.300000E 00    0.300000E 00    0.300000E 00
              THERMAL EXPANSION COEFFICIENTS                     RIGIDITY MODULI

                     DIRECTIONS                                    DIRECTIONS
TEMPERATURE
                XX              YY              ZZ              XY              YZ              ZX
    0.     0.125000E-04    0.125000E-04    0.125000E-04    0.120323E 08    0.120323E 08    0.120323E 08

***************************************************************************
```

255

FIGURE III-C.11 TITLE AND MATERIAL DATA OUTPUT, CANTILEVER BEAM

5 REF. POINTS

NO. DIRECTIONS = 3 NO. DEGREES OF FREEDOM = 6

GRIDPOINT DATA
(IN RECTANGULAR COORDINATES)

POINT	X	Y	Z	TEMPERATURES	PRESSURES
1	0.0	0.0	0.0	0.0 0.0 0.0	0.0 0.0 0.0
2	0.31495555E 03	0.0	0.0	0.0 0.0 0.0	0.0 0.0 0.0
3	0.31495555E 03	0.19659988E 02	0.0	0.0 0.0 0.0	0.0 0.0 0.0
4	0.0	0.19659988E 02	0.0	0.0 0.0 0.0	0.0 0.0 0.0
5	0.15[illegible]E 03	0.25[illegible]E 02	0.0	0.0 0.0 0.0	0.0 0.0 0.0

NOT REPRODUCIBLE

BOUNDARY CONDITION INFORMATION

NODES	DEGREES OF FREEDOM						NO. OF ONES	NO. OF TWOS
1	0	0	0	[illegible]	[illegible]	0	[illegible]	0
2	1	1	0	[illegible]	[illegible]	0	2	0
3	1	1	0	[illegible]	[illegible]	0	4	0
4	[illegible]	0	[illegible]	[illegible]	0	0	4	0
5	0	0	0	0	0	0	4	0

FIGURE III-C.12 GRIDPOINT DATA AND BOUNDARY CONDITION OUTPUT, CANTILEVER BEAM

```
                                  TOTAL NO. ELEMENTS =      5

ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NO.   --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  1  25    99399    0 -0.          2     4     1  2  3  4

MATERIAL NUMBER. . . . . . . . . 99399
      MATERIAL IDENTIFICATION. . . .  E=3.12E7 NU=0.30
      ANALYSIS CAPABILITY. . . . . .       ISOTROPIC
      INPUT PRINT CODE . . . . . . . . 1
      ELEMENT PRINT CODE . . . . . . .-1

INTERPOLATED MATERIAL PROPERTIES
      TEMPERATURE =       0.
      YOUNG'S MODULI                   0.31200000E 08      0.31200000E 08      0.31200000E 08
      POISSON'S RATIOS                 0.30000000E 00      0.30000000E 00      0.30000000E 00


      THERMAL EXPANSION COEFFICIENTS   0.12500000E-04      0.12500000E-04      0.12500000E-04
      RIGIDITY MODULI                  0.12032307E 08      0.12032307E 08      0.12032307E 08

INTERPOLATED PLASTIC PROPERTIES
      NONE

PRE-STRAIN INPUT
      NONE

PRE-STRESS INPUT
      NONE

EXTERNAL INPUT
          0.70700000E-01    -0.                 -0.                 -0.                 -0.

ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NO.   --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  2  11    99399    0 -0.          2     3     1  2  5

MATERIAL NUMBER. . . . . . . . . 99399
      MATERIAL IDENTIFICATION. . . .  E=3.12E7 NU=0.30
      ANALYSIS CAPABILITY. . . . . .       ISOTROPIC
      INPUT PRINT CODE . . . . . . . . 1
      ELEMENT PRINT CODE . . . . . . .-1

INTERPOLATED MATERIAL PROPERTIES
      TEMPERATURE =       0.
      YOUNG'S MODULI                   0.31200000E 08      0.31200000E 08      0.31200000E 08
      POISSON'S RATIOS                 0.30000000E 00      0.30000000E 00      0.30000000E 00
      THERMAL EXPANSION COEFFICIENTS   0.12500000E-04      0.12500000E-04      0.12500000E-04
      RIGIDITY MODULI                  0.12032307E 08      0.12032307E 08      0.12032307E 08

INTERPOLATED PLASTIC PROPERTIES
      NONE

PRE-STRAIN INPUT
      NONE

PRE-STRESS INPUT
      NONE

EXTERNAL INPUT
          0.15900000E 01    -0.                 -0.                 -0.                 -0.

ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NO.   --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  3  11    99399    0  0.          0     3     3  4  5                       0.1550E 01  -0.          -0.
  4  11    99399    0  0.          0     3     1  4  5                       0.1000E 00  -0.          -0.
  5  11    99399    0  0.          0     3     2  3  4                       0.1000E 00  -0.          -0.
```

FIGURE III-1.12 FINITE ELEMENT DESCRIPTIONS OUTPUT, CANTILEVER BEAM

```
                         EXTERNAL LOAD CONDITIONS   1

LOAC NO.   1
  NUMBER OF LOACEC NODES    2        ELEMENT LOAD SCALAR =  0.
3  0.          -0.17640E C3  0.        0.          0.          0.
4  0.          -0.17640E 03  0.        0.          0.          0.

                   TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN

                                  30 X 1

0.        0.                 0.        0.        0.        0.
0.        C.                 0.        0.        0.        0.
0.        -0.17640CCCE C3    0.        0.        0.        0.
0.        -0.17640CCCE C3    0.        0.        0.        0.
0.        0.                 0.        0.        0.        0.

                         T-ZERO FOR STRUCTURE =  0.
```

FIGURE III-C.14 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, CANTILEVER BEAM

NOT REPRODUCIBLE

MATRIX STIFF PAGE 1

CUTOFF = C. SIZE 4 BY 4

	FORCE		FORCE		FORCE		FORCE	
DISP. 1	1	0.395699E 07	2	-0.235736E 05	3	-C.380303E 07	4	-0.236736E 06
DISP. 2	1	-0.235736E 06	2	0.174300E 05	3	0.236736E 06	4	-0.144827E 06
DISP. 3	1	-0.380303E 07	2	C.236736E 05	3	0.395699E 07	4	0.236736E 06
DISP. 4	1	-0.236736E 05	2	-C.144827E 06	3	0.236736E 05	4	0.174300E 06

FIGURE III-C.15 REDUCED STIFFNESS MATRIX OUTPUT, CANTILEVER BEAM

GPRINT OF MATRIX LOADS (SET 1)

ROW	FX	FY	FZ	MX	MY	MZ
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	-0.17639999E 03	0.0	0.0	0.0	0.0
4	0.0	-0.17639999E 03	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0

DISPLACEMENT MATRIX FOR LOAD CONDITION 1

30 X 1

ROW	U	V	W	THETAX	THETAY	THETAZ
1	0.0	0.0	0.0	0.0	0.0	0.0
2	-0.52[illegible]25594E-02	-0.15055174E 00	0.0	0.0	0.0	0.0
3	0.52[illegible]26219E-02	-0.15110451E 00	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0

REACTIONS AND INVERSE CHECK FOR LOAD CONDITION 1

ROW	FX	FY	FZ	MX	MY	MZ
1	0.28336719E 04	0.88198242E 02	0.0	0.0	0.0	0.0
2	0.27343750E-01	0.78125000E-02	0.0	0.0	0.0	0.0
3	-0.55593750E-01	-0.10162354E-01	0.0	0.0	0.0	0.0
4	-0.2833[illegible]6E 04	0.26459814E 03	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE III-C.16 LOAD, DISPLACEMENT AND REACTION OUTPUT, CANTILEVER BEAM

```
S T R E S S E S   F O R   T H E   Q U A D R I L A T E R A L   S H E A R   P A N E L   E L E M E N T
                        (STRESSES EVALUATED AT ELEMENT CENTROID)

LOAD CONDITION NUMBER    ELEMENT NUMBER    ELEMENT TYPE       ELEMENT GRID POINTS
          1                     1               25              1    2    3    4

APPARENT ELEMENT STRESSES
STRESS
POINT             MEMBRANE SHEAR STRESS

  1                 -0.11432256E 03

ELEMENT APPLIED STRESSES
STRESS
POINT             MEMBRANE SHEAR STRESS

  1                  0.0

NET ELEMENT STRESSES
STRESS
POINT             MEMBRANE SHEAR STRESS

  1                 -0.11432256E 03
```


FIGURE III-C.17 STRESS OUTPUT, QUADRILATERAL SHEAR PANEL.
CANTILEVER BEAM

S T R E S S E S   F O R   T H E   F R A M E   E L E M E N T

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	2	11	1 2 5

APPARENT ELEMENT STRESSES

STRESS POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.14166103E 04	0.0	0.0	0.0	0.0	0.0
2	-0.14166103E 04	0.0	0.0	0.0	0.0	0.0

ELEMENT APPLIED STRESSES

STRESS POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.14166103E 04	0.0	0.0	0.0	0.0	0.0
2	-0.14166103E 04	0.0	0.0	0.0	0.0	0.0

FIGURE III-C.18 STRESS OUTPUT, AXIAL FORCE MEMBER NO. 1, CANTILEVER BEAM

S T R E S S E S   F O R   T H E   F R A M E   E L E M E N T

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	3	11	3 4 5

APPARENT ELEMENT STRESSES

STRESS POINT	FORCES AXIAL(FX)	SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(PZ)
1	-0.14168052E 04	0.0	0.0	0.0	0.0	0.0
2	0.14168052E 04	0.0	0.0	0.0	0.0	0.0

ELEMENT APPLIED STRESSES

STRESS POINT	FORCES AXIAL(FX)	SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(PZ)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	FORCES AXIAL(FX)	SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(PZ)
1	-0.14168052E 04	0.0	0.0	0.0	0.0	0.0
2	0.14168052E 04	0.0	0.0	0.0	0.0	0.0

FIGURE III-C.19 STRESS OUTPUT, AXIAL FORCE MEMBER NO. 2, CANTILEVER BEAM

S T R E S S E S   F O R   T H E   F R A M E   E L E M E N T

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	4	11	1 4 5

APPARENT ELEMENT STRESSES

STRESS POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0

ELEMENT APPLIED STRESSES

STRESS POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE III-C.20 STRESS OUTPUT, AXIAL FORCE MEMBER NO. 3, CANTILEVER BEAM

STRESSES FOR THE FRAME ELEMENT

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	5	11	[illegible] [illegible] 5

APPARENT ELEMENT STRESSES

STRESS POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.88263125E 02	0.0	0.0	0.0	0.0	0.0
2	-0.88263125E 02	0.0	0.0	0.0	0.0	0.0

ELEMENT APPLIED STRESSES

STRESS POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.88263125E 02	0.0	0.0	0.0	0.0	0.0
2	-0.88263125E 02	0.0	0.0	0.0	0.0	0.0

FIGURE III-C.21 STRESS OUTPUT, AXIAL FORCE MEMBER NO. 4, CANTILEVER BEAM

F O R C E S   F O R   T H E   Q U A D R I L A T E R A L   S H E A R   P A N E L   E L E M E N T

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	[illegible]	1 2 3 4

APPARENT ELEMENT FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.14166594E 04	0.88198242E 02	0.0	0.0	0.0	0.0
2	0.14166320E 04	-0.88198242E 02	0.0	0.0	0.0	0.0
3	-0.14166594E 04	-0.88198242E 02	0.0	0.0	0.0	0.0
4	-0.14166320E 04	0.88198242E 02	0.0	0.0	0.0	0.0

NOT REPRODUCIBLE

ELEMENT APPLIED FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.14166594E 04	0.88198242E 02	0.0	0.0	0.0	0.0
2	0.14166320E 04	-0.88198242E 02	0.0	0.0	0.0	0.0
3	-0.14166594E 04	-0.88198242E 02	0.0	0.0	0.0	0.0
4	-0.14166320E 04	0.88198242E 02	0.0	0.0	0.0	0.0

FIGURE III-C.22 FORCE OUTPUT, QUADRILATERAL SHEAR PANEL, CANTILEVER BEAM

F O R C E S   F O R   T H E   F R A M E   E L E M E N T

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	2	11	1 2 3

APPARENT ELEMENT FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.14168103E 04	0.0	0.0	0.0	0.0	0.0
2	-0.14168103E 04	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0

ELEMENT APPLIED FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0

NOT REPRODUCIBLE

NET ELEMENT FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.14168103E 04	0.0	0.0	0.0	0.0	0.0
2	-0.14168103E 04	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE III-C.23 FORCE OUTPUT, AXIAL FORCE MEMBER NO. 1, CANTILEVER BEAM

F O R C E S F O R T H E F R A M E E L E M E N T

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	3	11	[illegible]

APPARENT ELEMENT FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.14160052E 04	0.0	0.0	0.0	0.0	0.0
2	-0.14160052E 04	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0

ELEMENT APPLIED FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.14160052E 04	0.0	0.0	0.0	0.0	0.0
2	-0.14160052E 04	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE III-C.24 FORCE OUTPUT, AXIAL FORCE MEMBER NO. 2, CANTILEVER BEAM

FORCES FOR THE [illegible] ELEMENT

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	[illegible] POINTS
1	4	11	[illegible]

APPARENT ELEMENT FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.0	[illegible]	[illegible]	[illegible]	[illegible]	0.0
2	0.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	0.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

ELEMENT APPLIED FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.0	[illegible]	[illegible]	[illegible]	[illegible]	0.0
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0

NOT REPRODUCIBLE

NET ELEMENT FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	[illegible]	0.0	0.0	[illegible]	0.0	0.0
2	[illegible]	0.0	0.0	0.0	0.0	0.0
3	[illegible]	[illegible]	0.0	0.0	[illegible]	0.0

[illegible] TEST, AXIAL [illegible]

F O R C E S   F O R   T H E   [illegible]

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	5	11	2 3 5

APPARENT ELEMENT FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.0	0.88203125E 02	0.0	0.0	0.0	0.0
2	0.0	-0.88203125E 02	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0

ELEMENT APPLIED FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT FORCES

POINT	AXIAL(FX)	FORCES SHEAR(FY)	SHEAR(FZ)	TORQUE(MX)	FLEXURAL MOMENTS NORMAL(MY)	NORMAL(MZ)
1	0.0	0.88203125E 02	0.0	0.0	0.0	0.0
2	0.0	-0.88203125E 02	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE III-C.26 FORCE OUTPUT, AXIAL FORCE MEMBER NO. 4, CANTILEVER BEAM

D. THICK WALLED DISK

A thick walled disk under the influence of a radially varying thermal loading is shown in Figure III-D.1 along with its dimensions and pertinent material properties. This disk is idealized using triangular cross-section ring elements. The preprinted input data forms associated with this problem are shown in Figures III-D.2 through III-D.10.

In Figure III-D.3 (Material Tape Input Section) note that 2 material (temperature) points are entered for the material in question. A linear interpolation for material properties is performed for temperatures which fall between these two temperature points.

In Figure III-D.6 (Grid Point Temperature Section) it is instructive to note the use of the Repeat Option. Grid point 5 has the same temperature as grid point 1, therefore the Repeat option is employed by placing an 'X' in column 12 opposite the entry for Grid Point Number 5. This same procedure is also used for Grid Points 2 and 3. Note that the Grid Points are not entered sequentially allowing the use of the Repeat option. It should also be noted that the temperature values are entered in Columns 13-22.

In Figure III-D.7 (Boundary Condition Section) it is instructive to note the use of the MODAL option. There is only 1 exception to the MODAL card and this is Grid Point Number 5. This exception must be called out on the System Control Information Data Form (Figure III-D.4).

In Figure III-D.8 (External Loads Section) the following information is evident.

(1) One load condition is input

(2) The External Applied Load Scalar equals 1.0

(3) The MODAL option is employed, and loads of 0.0 are entered in the locations corresponding to F_x, F_y, and F_z. Note that this is the only entry required (the Moment and Generalized Values are ignored) since the Triangular Cross-Section ring has three degrees of freedom per point thus requiring only one external load card per grid point.

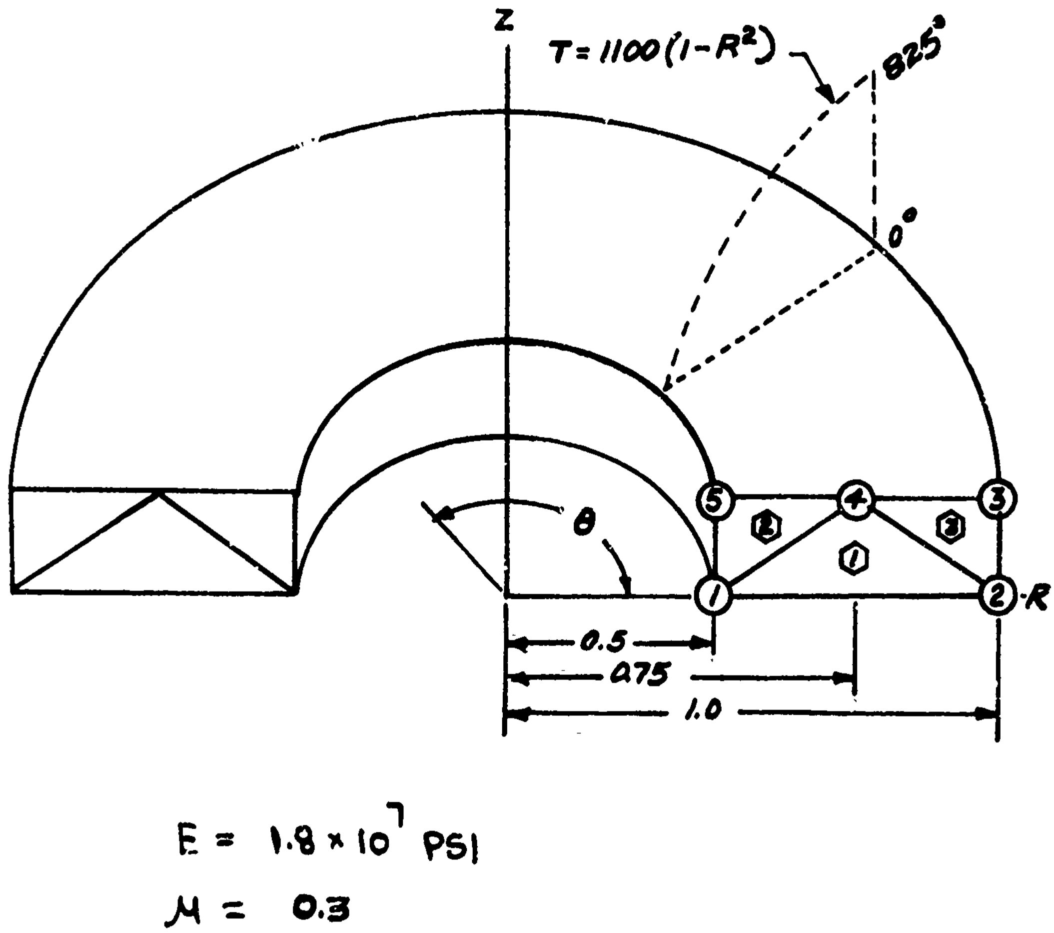


FIGURE III - D.1 - Idealized Thick Walled Disc

In Figure III-D.9 (Element Control Data Section) it is important to note a number of items.

(1) The temperature interpolate option (Col. 19) is employed for all three elements. The '3' entered in this location tells the system to average the three node point temperatures for each element and use this average temperature when establishing material properties from the material tape.

(2) The node point numbering sequence for each element is very important. Note that each element <u>must</u> be numbered in a counter-clockwise manner when looking in the positive element Y (θ) direction (Figure III-D.1).

Element Input is <u>not</u> required for this problem.

BAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

REPORT (/)

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

1 2 3 4 5 6
TITLE (/)

7 8 9
3 (/) NUMBER OF TITLE CARDS

```
THICK WALLED DI$K $UBJECTED TØ A RADIAL THERMAL GRADIENT 1100(1-R**2) (/)
THREE TRIANGULAR RING ELEMENT$ U$ED IN THE IDEALIZATIØN (/)
REFERENCE- WANG APPLIED ELA$TICITY- PAGE 70 (PLANE $TRE$$ FØRMULATIØN) (/)
(/)
(/)
(/)
(/)
(/)
(/)
```

FIGURE III-D.2 TITLE INFORMATION, THICK WALLED DISK

BAC 1616-1

MATER (/)
1 2 3 4 5 6

1 (/)
7 8 9
No. of Requests

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MATERIAL TAPE INPUT

Request Number (7-9)	Material Number (10-15)	Lock Code (16-17)	Material Identification (18-41)	Isotropic (42)	Orthotropic (43)	Plastic Isotropic (44)	Plastic Orthotropic (45)	Add Plastic (46)	Delete Material (47)	Print Tape (48)	Print Mat'l. Table (49)	Print Mat'l. Summary (50)	Number of Mat'l. Pts. (51-52)	Number of Plastic Pts. (53-54)	Mass Density (55-64)	
1	1	ZT	ALUMINUM - E=18E6, MU=0.30	X									2		00.00026	(/)

MATERIAL PROPERTIES TABLE

Temperature (13-22)	Direction	Youngs Moduli (23-32)	Direction	Poissons Ratios (33-42)	Direction	Coef. of Thermal Expansion (43-52)	Direction	Rigidity Moduli (53-62)	
0.0	E_x	1.8 E7	ν_{xy}	0.30	α_x	0.10 E-6	G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
825.0		1.8 E7		0.30		0 10 E-6			(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

FIGURE III-D.3 MATERIAL TAPE INPUT, THICK WALLED DISK

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

<u>SYSTEM CONTROL INFORMATION</u>

> ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

Item	Entry	Columns
	S Y S T E M (/)	1 2 3 4 5 6
1. Number of System Grid Points	5	1 2 3 4 5 6
2. Number of Input Grid Points	5	7 8 9 10 11 12
3. Number of Degrees of Freedom/Grid Point	3	13 14
4. Number of Load Conditions	1	15 16
5. Number of Initially Displaced Grid Points		17 18 19 20 21 22
6. Number of Prescribed Displaced Grid Points		23 24 25 26 27 28
7. Number of Grid Point Axes Transformation Systems		29 30
8. Number of Elements	3	31 32 33 34 35 36
9. Number of Requests and/or Revisions of Material Tape.	1	37 38
10. Number of Input Boundary Condition Points	1	39 40 41 42 43 44
11. T_o For Structure (With Decimal Point)	0.0 (/)	45 46 47 48 49 50 51 52

FIGURE III-D.4 SYSTEM CONTROL INFORMATION, THICK WALLED DISK

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6
C	O	O	R	D	

(/)

GRIDPOINT COORDINATE

	COORD. INPUT	$
SYSTEM	RECTANGULAR	R/Δ
	CYLINDRICAL	C
	SPHERICAL	S

Δ = BLANK

$ (5)	(6)	Grid Point Number (7–12)	X – R (13–22)	Y – θ (23–32)	Z – Z (33–42)	
		1	0.50	0.0	0.0	(/)
		2	1.00	0.0	0.0	(/)
		3	1.00	0.0	0.1	(/)
		4	0.75	0.0	0.1	(/)
		5	0.50	0.0	0.1	(/)

FIGURE III-D.5 GRIDPOINT COORDINATES, THICK WALLED DISK

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

GRID POINT TEMPERATURES

1	2	3	4	5	6	
T	E	M	P			(/)

1 2 3 4 5 6	TEMPERATURES: T_1 (13–22)	T_2 (23–32)	T_3 (33–42)	
MODAL				(/)

Grid Point Number (7 8 9 10 11)	Repeat (12)	T_1 (13–22)	T_2 (23–32)	T_3 (33–42)	
1		825.0			(/)
5	X				(/)
2		0.0			(/)
3	X				(/)
4		481.25			(/)

FIGURE III.D.6 GRIDPOINT TEMPERATURES, THICK WALLED DISK

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE - 0 - No Displacement Allowed
1 - Unknown Displacement
2 - Known Displacement

1	2	3	4	5	6
B	O	U	N	D	

(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	Θx	Θy	Θz	1	2	3	
13	14	15	16	17	18	19	20	21	
1	0	1							(/)

LISTED INPUT

Grid Point Number					Repeat										
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
				5		1	0	0							(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
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															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)

FIGURE III-D.7 BOUNDARY CONDITIONS, THICK WALLED DISK

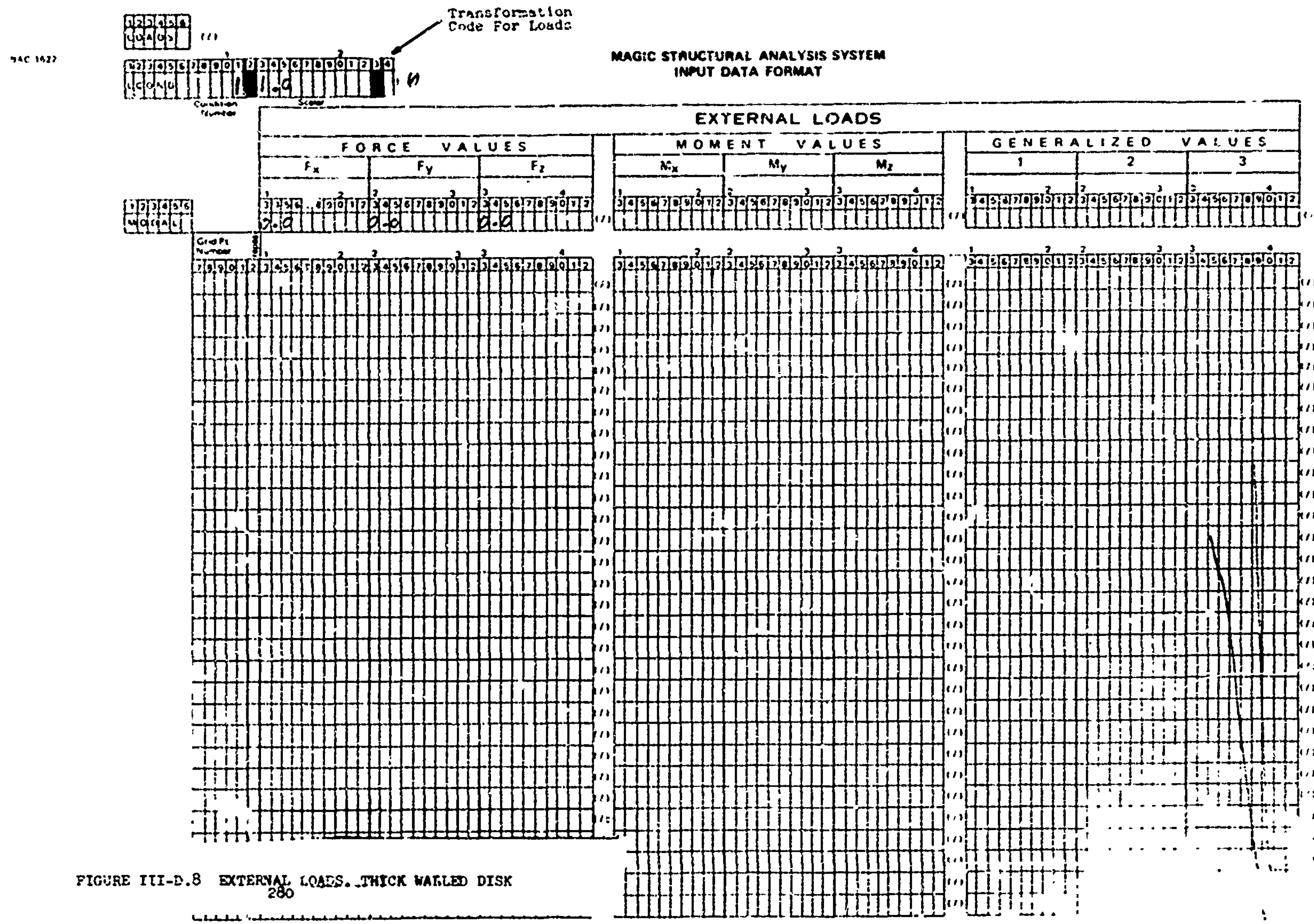

FIGURE III-D.8 EXTERNAL LOADS. THICK WALLED DISK

BAC 1626

ELEM (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

Element Number (7-10)	Plug No. (11-12)	Material Number (13-18)	Interpolate Option (19)	Material Temperature (20-27)	Repeat Elem. Matrices (28)	Elem. Input (29)	Print: Print (30)	Print: Elem. Mat. (31)	Print: Full (32)	Number of Input Nodes (33-34)	Suppress Pressures (35)	Node Points 1 (36-38)	2 (39-41)	3 (42-44)	4	5	6	7	8	9	10	11	12
1	40	12	3						X	3		1	2	4									
2	40	12	3							3		1	4	5									
3	40	12	3							3		2	3	4									

FIGURE III-D.9 ELEMENT CONTROL DATA, THICK WALLED DISK

CHECK OR END CARD

C	H	E	C	K	(/)
1	2	3	4	5	

E	N	D	(/)
1	2	3	

FIGURE III-D.10 END CARD, THICK WALLED DISK

The output supplied by the MAGIC System for the thick walled disk is as follows:

Figures III-D.11 thru III-D.14 display the output from the Structural Systems Monitor. These figures display the input data pertinent to the particular problem being solved.

Figure III-D.12 displays the coordinate and boundary condition information for this problem.

In the Gridpoint Data Section note that node points 1 and 5 have temperature values input of 825.00 while node point 4 has a temperature of 481.25.

In the Boundary Condition Section note that there are three allowable degrees of freedom per point for the triangular ring element as follows:

(u, o, w). The ordering of the reduced displacement vector is as follows:

$$\{q\}^T = \lfloor u_1, w_1, u_2, w_2, u_3, w_3, u_4, w_4, u_5 \rfloor$$

Figure III-D.14 displays the Transformed External Assembled Load Column. Note that these loads are all equal to zero since this is a thermal stress problem and thermal loads are element applied loads.

MAGIC System output of final results is shown in Figure III-D.15 thru III-D.22.

Figure III-D.15 shows the assembled and reduced stiffness matrix. The stiffness matrix is presented row-wise and only non-zero terms are displayed. The ordering of the stiffness matrix is consistent with that of the boundary conditions shown in Figure III-D.12. For this case the order of the displacement vector is as follows:

$$\{q\}^T = \lfloor u_1, w_1, u_2, w_2, u_3, w_3, u_4, u_5 \rfloor$$

The thermal load vector (GPRINT OF MATRIX FTELA) is displayed in Figure III-D.16. These forces are generated at the element level and are output with respect to node point number.

The displacements of the thick walled disk which result from the imposed temperature distribution are also presented in Figure III-D.16. It is noted that displacements (U, V, W) are output corresponding to node point number and are referenced to the global axis unless otherwise specified.

The final items of information contained in Figure III-D.16 are the Reactions. The reactions are listed corresponding to node point number. Note that for this particular application, the reactions are effectively equal to zero which results from the nature of the thermal loading which is imposed.

Stresses for each Triangular Ring Element are shown in Figures III-D.17 thru III-D.19. All stresses are evaluated at the element centroids.

The stresses for each element are defined as follows:

$$\sigma = [E]\{\epsilon\} - \{SZAEL\}$$

where from Figure III-D.17:

$$[E]\{\epsilon\} = \text{Apparent Element Stress}$$

$$\{SZAEL\} = \text{Element Applied Stress}$$

$$\{\sigma\} = \text{Net Element Stress}$$

The thermal stress correction vector $\{SZAEL\}$ for any particular element is defined as follows:

$$\{SZAEL\} = \Delta T \quad [E] \quad \{\bar{\alpha}\}$$

where $[E]$ is the material property matrix which has the following form

$$E = \frac{1}{\Delta}\begin{bmatrix} E_r(1-\nu_{\theta z}\nu_{z\theta}), & E_r(\nu_{\theta r}+\nu_{zr}\nu_{\theta z}), & E_r(\nu_{zr}+\nu_{z\theta}\nu_{\theta r}), & 0 \\ & E_\theta(1-\nu_{rz}\nu_{zr}) & , E_\theta(\nu_{z\theta}+\nu_{r\theta}\nu_{zr}), & 0 \\ & & E_z(1-\nu_{r\theta}\nu_{\theta r}) & , 0 \\ \text{Symmetric} & & & \Delta G_{rz} \end{bmatrix}$$

where

$$\Delta = (1-\nu_{r\theta}\nu_{\theta r}-\nu_{\theta z}\nu_{z\theta}-\nu_{zr}\nu_{rz}-\nu_{r\theta}\nu_{\theta z}\nu_{zr}-\nu_{rz}\nu_{\theta r}\nu_{z\theta})$$

$$\{\bar{\alpha}\}^T = \lfloor \alpha_r, \alpha_\theta, \alpha_z, 0 \rfloor$$

where α_r, α_θ, and α_z are the coefficients of thermal expansion in the r, e, and z directions respectively. ΔT is the difference between the centroidal temperature of the element and the equilibrium temperature.

Rewrite the material properties matrix as follows:

$$[E] = \begin{bmatrix} E_{11} & E_{12} & E_{13} & 0 \\ & E_{22} & E_{23} & 0 \\ & & E_{33} & 0 \\ \text{SYMM.} & & & E_{44} \end{bmatrix}$$

Using this notation, the SZAEL vector (Element Applied Stresses) for Element No. 1 is interpreted as follows:

ELEMENT NUMBER	ALGEBRAIC VALUE	NUMERICAL VALUE
1 (σr)	$(E_{11} \alpha_r + E_{12} \alpha_\theta + E_{13} \alpha_z)$	1959.37
1 ($\sigma \theta$)	$(E_{12} \alpha_r + E_{22} \alpha_\theta + E_{23} \alpha_z)$	1959.37
1 (σz)	$(E_{13} \alpha_r + E_{23} \alpha_\theta + E_{33} \alpha_z)$	1959.37

The stresses for Element Numbers 2 and 3 (Figures III-D.18 and 19) are presented in exactly the same manner as in Figure III-D.17.

Element forces for this application are presented in Figures III-D.20 thru III-D.22. These forces are defined with respect to the Global Coordinate System. Each Triangular Ring Element has three element forces defined per grid point (F_r, F_θ, F_z). For Element No. 1 (Figure III-D,20) Force points 1, 2 and 3 correspond to node points 1, 2 and 4 respectively. Forces for Element Numbers 2 and 3 are defined in an analogous manner (Figures III-D.21 and 22).

```
THICK WALLED DISK SUBJECTED TO A RADIAL THERMAL GRADIENT 1100(1-R**2)

THREE TRIANGULAR RING ELEMENTS USED IN THE IDEALIZATION

REFERENCE- WANG APPLIED ELASTICITY-PAGE 70(PLANE STRESS FORMULATION)

                    REVISIONS OF MATERIAL TAPE

                 ASTERISK (*) PRECEEDING MATERIAL
                 IDENTIFICATION INDICATES THAT INPUT
                 ERROR RETURNS WILL NOT RESULT IN
                     TERMINATION OF EXECUTION

*****************************************************************************

REVISION
  MATERIAL NUMBER      12                                   INPUT CODE   1
  MATERIAL IDENTIFICATION    E=1.8E6,MU=0.30
    NUMBER OF MATERIAL PROPERTY POINTS. . . .  2
    NUMBER OF PLASTIC PROPERTY POINTS . . . . -0
    MASS DENSITY. . . . . . . . . . . . . . . -0.

  MATERIAL PROPERTIES
                         YOUNG'S MODULI                                   POISSON'S RATIOS

                           DIRECTIONS                                        DIRECTIONS

TEMPERATURE                                                   XY               YZ               ZX
                 XX              YY              ZZ
     0.      0.180000E 09    0.180000E 08    0.180000E 08    0.300000E 00     0.300000E 00     0.300000E 00
  1500.00    0.180000E 09    0.180000E 08    0.190000E 08    0.300000E 00     0.300000E 00     0.300000E 00
                   THERMAL EXPANSION COEFFICIENTS                          RIGIDITY MODULI

                           DIRECTIONS                                        DIRECTIONS

TEMPERATURE                                                   XY               YZ               ZX
                 XX              YY              ZZ
     0.      0.100000E-05    0.100000E-06    0.100000E-06    0.692308E 07     0.692308E 07     0.692308E 07
  1500.00    0.100000E-06    0.100000E-06    0.100000E-06    0.692308E 07     0.692308E 07     0.692308E 07

*****************************************************************************
```

FIGURE III-D.11 TITLE AND MATERIAL DATA OUTPUT, THICK WALLED DISK

5 REF. POINTS

NO. DIRECTIONS = 3   NO. DEGREES OF FREEDOM = 1

GRIDPOINT DATA
(IN RECTANGULAR COORDINATES)

POINT	X	Y	Z	TEMPERATURES	PRESSURES
1	0.50000000E 00	0.0	0.0	0.82500000E 03	0.0
				0.0	0.0
				0.0	0.0
2	0.10000000E 01	0.0	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
3	0.15000000E 01	0.0	0.99999964E-01	0.0	0.0
				0.0	0.0
				0.0	0.0
4	0.75000000E 00	0.0	0.99999964E-01	0.48125000E 03	0.0
				0.0	0.0
				0.0	0.0
5	0.50000000E 00	0.0	0.99999964E-01	0.82500000E 03	0.0
				0.0	0.0
				0.0	0.0

BOUNDARY CONDITION INFORMATION

NODES	DEGREES OF FREEDOM			NO. OF ONES	NO. OF TWOS
1	1	0	1	2	0
2	1	0	1	4	0
3	1	0	1	6	0
4	1	0	1	8	0
5	1	0	0	9	0

FIGURE III-D.12 GRIDPOINT DATA AND BOUNDARY CONDITION INPUT, THICK WALL [illegible]

```
                                   TOTAL NO. ELEMENTS =     3

ELEM TYPE  MAT.NO. CODE   TEMP.    PRNT  NO.     --------GRID POINTS--------    EXTRA GRID PTS    ------SECTION PROPERTIES------
  1  40       12     0 -0.            2    3       1   2   4

MATERIAL NUMBER. . . . . . . .  12
      MATERIAL IDENTIFICATION. . . .  E=1.8E6,MU=0.30
      ANALYSIS CAPABILITY. . . . . .       ISCTROPIC
      INPUT PRINT CODE . . . . . . .  1
      ELEMENT PRINT CODE . . . . . . -1

INTERPOLATED MATERIAL PROPERTIES
      TEMPERATURE -       0.43541667E 03
      YOUNG'S MODULI                          0.18000000E 08    0.18000000E 08    0.18000000E 08
      POISSON'S RATIOS                        0.30000000E 00    0.30000000E 00    0.30000000E 00


      THERMAL EXPANSION COEFFICIENTS          0.10000000E-06    0.10000000E-06    0.10000000E-06
      RIGICITY MODULI                         0.69230769E 07    0.69230769E 07    0.69230769E 07

INTERPOLATED PLASTIC PROPERTIES
      NONE

PRE-STRAIN INPUT
      NONF

PRE-STRESS INPUT
      NONE

EXTERNAL INPUT
      NONE

ELEM TYPE  MAT.NO. CODE   TEMP.    PRNT  NO.     --------GRID POINTS--------    EXTRA GRID PTS    ------SECTION PROPERTIES------
  2  40       12     0  0.7104E 03  0     3      1   4   5                                       0.          0.          0.
  3  40       12     0  0.1604E 03  0     3      4   2   3                                       0.          0.          0.
```

FIGURE III-D.13 FINITE ELEMENT DESCRIPTION OUTPUT, THICK WALLED DISK

```
                         EXTERNAL LOAD CONDITIONS   1

LOAD NO.   1
  NUMBER OF LOADED NODES     1          ELEMENT LOAD SCALAR =  0.10000000E 01
1  0.          0.          0.

                  TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN
                                   15 X 1
 0.          0.          0.          0.          0.          0.
 0.          0.          0.          0.          0.          0.
 0.          0.          0.

                         T-ZERO FOR STRUCTURE =  0.
```

FIGURE III-D.14 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, THICK WALLED DISK

MATRIX STIFF PAGE 1

CUTOFF = 0. SIZE 9 BY 9

		FORCE		FORCE		FORCE		FORCE		FORCE	
DISP.	1	1	0.622780E 09	2	0.149528E 08	3	0.953554E 07	4	0.135934E 07	7	-0.398539E 08
		8	-0.317180E 08	9	-0.324430E 08						
DISP.	2	1	0.149528E 08	2	0.185641E 09	3	-0.579671E 07	4	0.681031E 08	7	-0.407803E 08
		8	-0.142731E 09	9	0.163121E 08						
DISP.	3	1	0.953554E 07	2	-0.579671E 07	3	0.846207E 08	4	-0.258275E 08	5	-0.485244E 08
		6	-0.172183E 08	7	-0.399857E 08	8	0.498426E 08				
DISP.	4	1	0.135934E 07	2	0.681031E 08	3	-0.258275E 08	4	0.249077E 09	5	-0.326242E 08
		6	-0.174449E 09	7	0.407803E 08	8	-0.142731E 09				
DISP.	5	3	-0.485244E 08	4	-0.326242E 08	5	0.801600E 08	6	0.525513E 08	7	-0.276812E 08
		8	-0.199370E 08								
DISP.	6	3	-0.172183E 08	4	-0.174449E 09	5	0.525513E 08	6	0.182424E 09	7	-0.271869E 08
		8	-0.797481E 07								
DISP.	7	1	-0.398539E 08	2	-0.407803E 08	3	-0.399857E 08	4	0.407803E 08	5	-0.276812E 08
		6	-0.271869E 08	7	0.128392E 09	8	0.543737E 07	9	-0.173996E 08		
DISP.	8	1	-0.317180E 08	2	-0.142731E 09	3	0.498426E 08	4	-0.142731E 09	5	-0.199370E 08
		6	-0.797481E 07	7	0.543737E 07	8	0.298512E 09	9	0.126872E 08		
DISP.	9	1	-0.324430E 08	2	0.163121E 08	7	-0.173996E 08	8	0.126872E 08	9	0.476676E 08

FIGURE III-D.15 REDUCED STIFFNESS MATRIX OUTPUT, THICK WALLED DISK

PRINT OF MATRIX FIELD [illegible]

ROW	FX	FY	FZ
1	-[illegible].27537964E 03	[illegible]	-[illegible]
2	[illegible].56[illegible]15525E 03	[illegible]	-[illegible]
3	[illegible].22[illegible]7[illegible]323E 03	[illegible]	[illegible]51971216E [illegible]
4	[illegible]5552E 03	[illegible]	[illegible]23 [illegible]5269E [illegible]
5	-[illegible].5[illegible]216211E 03	[illegible]	[illegible].14[illegible]389E [illegible]

DISPLACEMENT MATRIX FOR LOAD CONDITION 1

15 X 1

ROW	U	V	W
1	[illegible].24[illegible]9553[illegible]E-04	0.[illegible]	-0.86576274E-05
2	0.42943531E-04	0.[illegible]	-0.47132489E-05
3	0.4149[illegible]559E-04	0.[illegible]	-[illegible].43616747E-05
4	[illegible].3551[illegible]26E-04	0.[illegible]	-[illegible].21698506E-05
5	0.22752647E-04	0.[illegible]	[illegible]

REACTIONS AND INVERSE CHECK FOR LOAD CONDITION 1

ROW	FX	FY	FZ
1	[illegible].122[illegible]7031E-02	0.[illegible]	[illegible].21972656E-02
2	[illegible].1464[illegible] 37E-02	0.[illegible]	0.1953125[illegible]E-02
3	-[illegible].25482178E-02	0.[illegible]	-0.122[illegible]7031E-02
4	-0.40[illegible]86715E-02	0.0	-[illegible].170898[illegible]E-02
5	0.244140625E-03	0.0	0.1223[illegible]531E-02

FIGURE III-D.16 ELEMENT APPLIED LOADS, DISPLACEMENT & REACTION OUTPUT, THICK WALLED [illegible]

STRESSES FOR THE TRIANGULAR CROSS SECTION RING ELEMENT

(STRESSES EVALUATED AT ELEMENT [illegible] 1)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	4[illegible]	1 [illegible] 4

APPARENT ELEMENT STRESSES

STRESS POINT	RADIAL (SIGMA-R)	CIRCUMFERENTIAL (SIGMA-THETA)	AXIAL (SIGMA-Z)	SHEAR (SIGMA-RZ)
1	0.18309243E 04	0.19591769E 04	0.19490333E 04	.17324269E 03

ELEMENT APPLIED STRESSES

STRESS POINT	RADIAL (SIGMA-R)	CIRCUMFERENTIAL (SIGMA-THETA)	AXIAL (SIGMA-Z)	SHEAR (SIGMA-RZ)
1	0.15593711E 04	0.15593711E 04	0.15593711E 04	0.

NET ELEMENT STRESSES

STRESS POINT	RADIAL (SIGMA-R)	CIRCUMFERENTIAL (SIGMA-THETA)	AXIAL (SIGMA-Z)	SHEAR (SIGMA-RZ)
1	-0.12844678E 03	-0.20019531E 00	-0.95378418E 01	0.17324266E 03

FIGURE III-D.17 STRESS OUTPUT, ELEMENT NO. 1, THICK WALLED DISK

S T R E S S E S   F O R   T H E   T R I A N G U L A R   C R O S S   S E C T I [illegible]   R I N G   E L E M E N T

(STRESSES EVALUATED AT ELEMENT CENTROID)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	2	40	1 [illegible] [illegible]

APPARENT ELEMENT STRESSES

STRESS POINT	RADIAL (SIGMA-R)	CIRCUMFERENTIAL (SIGMA-THETA)	AXIAL (SIGMA-Z)	SHEAR (SIGMA-RZ)
1	0.262911946E 04	0.257741111E 04	0.312[illegible]322E 04	-0.1921[illegible]327E 03

ELEMENT APPLIED STRESSES

STRESS POINT	RADIAL (SIGMA-R)	CIRCUMFERENTIAL (SIGMA-THETA)	AXIAL (SIGMA-Z)	SHEAR (SIGMA-RZ)
1	0.319686699E 04	0.319686695E 04	0.319686699E 04	0.0

NET ELEMENT STRESSES

STRESS POINT	RADIAL (SIGMA-R)	CIRCUMFERENTIAL (SIGMA-THETA)	AXIAL (SIGMA-Z)	SHEAR (SIGMA-RZ)
1	-0.568759549E 03	-0.619453874E 03	-0.768376466E 02	-0.1921[illegible]327E 03

FIGURE III-D.18 STRESS OUTPUT, ELEMENT NO. 2, THICK WALLED DISK

STRESSES FOR THE TRIANGULAR CROSS SECTION RING ELEMENT

(STRESSES EVALUATED AT ELEMENT CENTROIDS)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT NODAL POINTS
1	3	40	4 2 [illegible]

APPARENT ELEMENT STRESSES

STRESS POINT	RADIAL (SIGMA-R)	CIRCUMFERENTIAL (SIGMA-THETA)	AXIAL (SIGMA-Z)	SHEAR (SIGMA-RZ)
1	0.10684692E 04	0.13414370E 04	0.78637573E 03	-0.16125925E 03

ELEMENT APPLIED STRESSES

STRESS POINT	RADIAL (SIGMA-R)	CIRCUMFERENTIAL (SIGMA-THETA)	AXIAL (SIGMA-Z)	SHEAR (SIGMA-RZ)
1	0.72167354E 03	0.72167354E 03	0.72167354E 03	0.0

NET ELEMENT STRESSES

STRESS POINT	RADIAL (SIGMA-R)	CIRCUMFERENTIAL (SIGMA-THETA)	AXIAL (SIGMA-Z)	SHEAR (SIGMA-RZ)
1	0.34679565E 03	0.61976343E 03	0.64702197E 02	-0.16125925E 03

FIGURE III-D.19 STRESS OUTPUT, ELEMENT NO. 3, THICK WALLED DISK

FORCES FOR THE TRIANGULAR CROSS SECTION RING ELEMENT

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	[illegible]	1 2 4

APPARENT ELEMENT FORCES

POINT	RADIAL (FR)	CIRCUMFERENTIAL (F-THETA)	AXIAL (FZ)
1	-0.43[illegible]66694E 03	0.0	-0.113[illegible]3655E 04
2	0.43193433E 03	0.0	-0.11[illegible]772030E 04
3	0.30667896E 03	0.0	0.2297[illegible]918E 04

ELEMENT APPLIED FORCES

POINT	RADIAL (FR)	CIRCUMFERENTIAL (F-THETA)	AXIAL (FZ)
1	-0.35907349E 03	0.0	-0.11541643E 04
2	0.56425781E 03	0.0	-0.11541643E 04
3	0.10259232E 03	0.0	0.23083289E 04

NET ELEMENT FORCES

POINT	RADIAL (FR)	CIRCUMFERENTIAL (F-THETA)	AXIAL (FZ)
1	-0.71793457E 02	0.0	-0.35291172E 02
2	-0.13232349E 03	0.0	0.46437988E 02
3	0.20466664E 03	0.0	-0.11237061E 02

FIGURE III-D.25 FORCE OUTPUT, ELEMENT NO. 1, THICK WALLED DISK

NOT REPRODUCIBLE

FORCES FOR THE TRIANGULAR CROSS SECTION RING ELEMENT

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	2	40	1 4 5

APPARENT ELEMENT FORCES

POINT	RADIAL (FR)	CIRCUMFERENTIAL (F-THETA)	AXIAL (FZ)
1	0.15546779E 03	0.0	-0.14294351E 04
2	0.54910276E 03	0.0	-0.35204345E 02
3	-0.50216187E 03	0.0	0.14640401E 04

ELEMENT APPLIED FORCES

POINT	RADIAL (FR)	CIRCUMFERENTIAL (F-THETA)	AXIAL (FZ)
1	0.83653771E 02	0.0	-0.14646389E 04
2	0.66954532E 03	0.0	0.0
3	-0.50216211E 03	0.0	0.14646389E 04

NET ELEMENT FORCES

POINT	RADIAL (FR)	CIRCUMFERENTIAL (F-THETA)	AXIAL (FZ)
1	0.71794022E 02	0.0	0.35203857E 02
2	-0.12044556E 03	0.0	-0.35204346E 02
3	0.24414062E-03	0.0	0.12207031E-02

NOT REPRODUCIBLE

FIGURE III-D.21 FORCES IN THE ELEMENT ... THICK WALLED ...

FORCES FOR THE TRIANGULAR CROSS SECTION RING ELEMENT

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	3	40	4 2 3

APPARENT ELEMENT FORCES

POINT	RADIAL (FR)	CIRCUMFERENTIAL (F-THETA)	AXIAL (FZ)
1	-0.27263080E 03	0.0	0.46439346E 02
2	0.15122294E 03	0.0	-0.56514917E 03
3	0.22678584E 03	0.0	0.51971113E 03

ELEMENT APPLIED FORCES

POINT	RADIAL (FR)	CIRCUMFERENTIAL (F-THETA)	AXIAL (FZ)
1	-0.18858602E 03	0.0	0.0
2	0.18858666E 02	0.0	-0.51971216E 03
3	0.22678323E 03	0.0	0.51971216E 03

NET ELEMENT FORCES

POINT	RADIAL (FR)	CIRCUMFERENTIAL (F-THETA)	AXIAL (FZ)
1	-0.83644836E 02	0.0	0.46439346E 02
2	0.13232425E 03	0.0	-0.46437012E 02
3	-0.23952994E-02	0.0	-0.97656250E-03

FIGURE III-D.22 FORCE OUTPUT, ELEMENT NO. 3, THICK WALLED DISK

E. THIN WALLED CYLINDER, EDGE LOADING

A thin walled cylinder is shown in Figure III-E.1, along with its loading, dimensions, and pertinent material properties. This cylinder is idealized using two toroidal thin shell ring elements. The preprinted input data forms associated with this cylinder are shown in Figures III-E.2 through III-E.10.

In Figure III-E.6 (Boundary Condition Section) the User should note that all nine degrees of freedom are required for the Toroidal Ring Element (u, 0, w, 0, θy, 0, u', 0, w").

In Figure III-E.7 (External Loads Section) the following items are evident.

(1) One load condition is entered.

(2) The External Applied Load Scalar is equal to zero.

(3) Grid point number 2 is loaded by the following load in the X(R) direction.

F_R = 188495.4 lbs. This load was determined as follows (From Figure III-E.1).

$$F_R = (1500 \text{ lbs./in.})(2\pi r)$$

$$F_R = (1500)(2)(3.14)(20) = 188{,}495.4 \text{ lbs.}$$

The value which is entered for the applied moment was determined as follows: (From Fiugre III-E.1).

$$M_{y(\theta)} = (1000 \text{ in.-lb./in.})(2\pi r) = 125{,}663.6 \text{ in.-lb.}$$

(4) All three entries are filled in for the Toroidal Ring because this element requires <u>three</u> <u>external</u> <u>load</u> <u>cards</u> per grid point.

In Figure III-E.9 (Element Input Section) only the MODAL entry is employed. This means that the two Toroidal Ring elements employed in this analysis have identical Element Input as follows:

Location A - Thickness = 3.0 inches

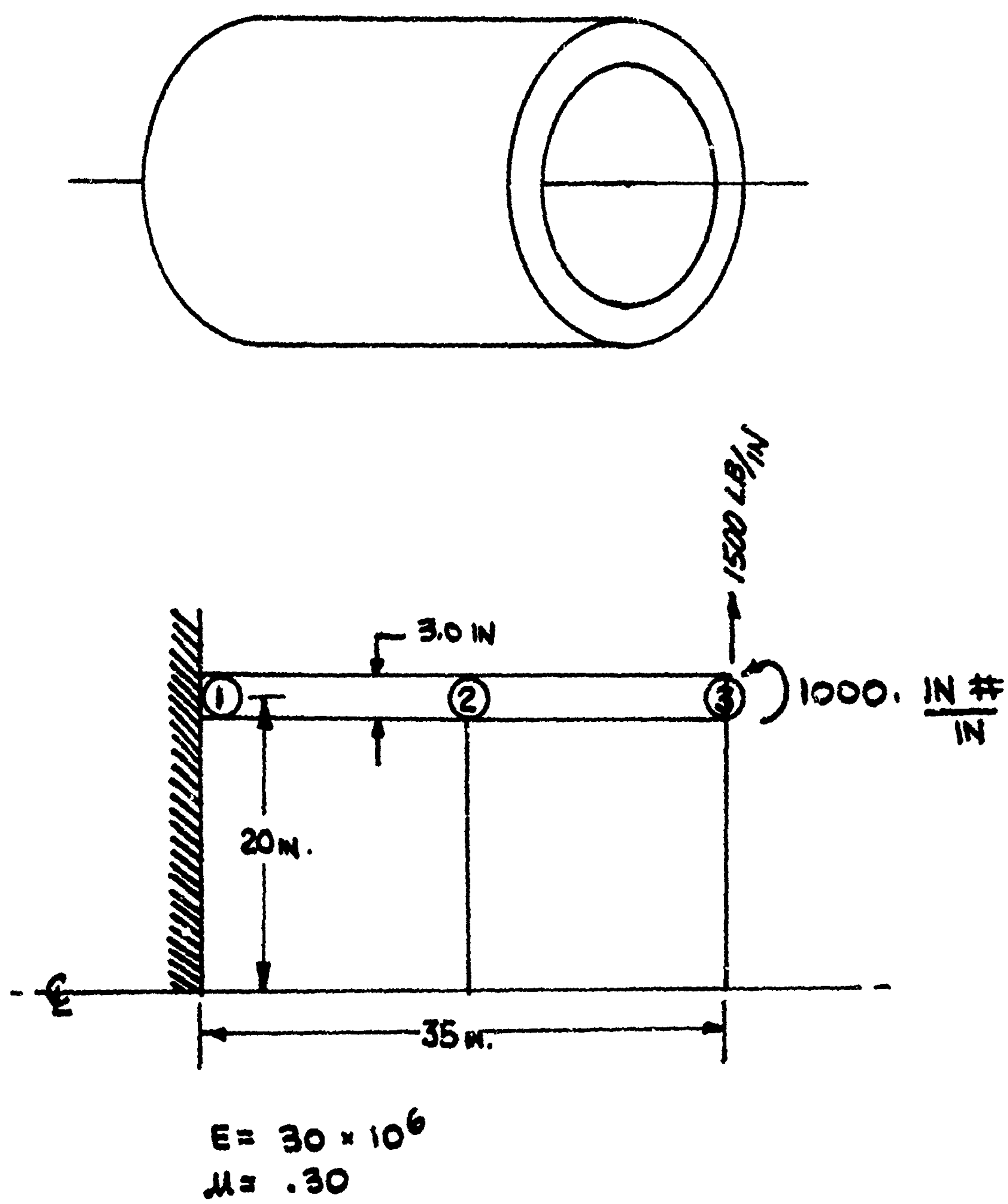

FIGURE III - E.1 - Idealized Thin Walled Cylinder with Edge Load

Location B - TCØ = 0.0 (This code determines the axis of reference for the display of displacement behavior, in this case the axis of reference is global).

Location C - Alpha 1 = 90.0 Degrees

Location D - Alpha 2 = 90.0 Degrees

For a review of the required Element Input for the Toroidal Ring the reader is referred to Section II-C.16.d.

BAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

REPORT (/)

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

1 2 3 4 5 6

TITLE (/)

7 8 9

5 (/) NUMBER OF TITLE CARDS

CYLINDRICAL $HELL $UBJECTED TØ END LØADING$ (/)

TWØ TØRØIDAL RINGS ELEMENT$ U$ED IN THE IDEALIZATIØN (/)

REFERENCE-KLEIN,$. $TUDY ØF THE MATRIX DI$PLACEMENT METHØD APPLIED (/)

TØ $HELL$ ØF REVØLUTIØN, CØNFERENCE ØN MATRIX METHØDS IN $TR.MECH. (/)

WRIGHT PATER$ØN AFB, 1965. (/)

(/)

(/)

(/)

(/)

FIGURE III-E.2 TITLE INFORMATION, THIN WALLED CYLINDER

SAC 1616-1

MATEM (/)
1 2 3 4 5 6

1 (/)
7 8 9
No. of Requests

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MATERIAL TAPE INPUT

Request Number (7–9)	MATERIAL NUMBER (10–15)	Lock Code (16–17)	MATERIAL IDENTIFICATION (18–41)	Isotropic (42)	Orthotropic (43)	Plastic Isotropic (44)	Plastic Orthotropic (45)	Add Plastic (46)	Delete Material (47)	Print Tape (48)	Print Mat'l. Table (49)	Print Mat'l. Summary (50)	Number of Mat'l. Pts. (51–52)	Number of Plastic Pts. (53–54)	MASS DENSITY (55–64)	
1	12TU		E = 3.0 E6, MU = 0.3	X							X		1	0	0.0002	(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE (13–22)	Direction	YOUNGS MODULI (23–32)	Direction	POISSONS RATIOS (33–42)	Direction	COEF. OF THERMAL EXPANSION (43–52)	Direction	RIGIDITY MODULI (53–62)	
0.0	E_x	3.0E06	ν_{xy}	0.3	α_x	12.5E-6	G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

FIGURE III-E.3 MATERIAL TAPE INPUT, THIN WALLED CYLINDER

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

Item	Request	Columns	Entry
		1–6	S Y S T E M (/)
1.	Number of System Grid Points	1–6	3
2.	Number of Input Grid Points	7–12	3
3.	Number of Degrees of Freedom/Grid Point	13–14	9
4.	Number of Load Conditions	15–16	1
5.	Number of Initially Displaced Grid Points	17–22	
6.	Number of Prescribed Displaced Grid Points	23–28	
7.	Number of Grid Point Axes Transformation Systems	29–30	
8.	Number of Elements	31–36	2
9.	Number of Requests and/or Revisions of Material Tape.	37–38	1
10.	Number of Input Boundary Condition Points	39–44	1
11.	T_o For Structure (With Decimal Point)	45–52	0 (col. 45), 0 (col. 47) (/)

FIGURE III-E.4 SYSTEM CONTROL INFORMATION, THIN WALLED CYLINDER

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1 2 3 4 5 6

| C | O | O | | | | (/) |

GRIDPOINT COORDINATE

COORD. INPUT	$
RECTANGULAR	R/Δ
CYLINDRICAL	C
SPHERICAL	S

SYSTEM

Δ = BLANK

$ (col 5)	(col 6)	Grid Point Number (7–12)	X – R (13–22)	Y – Θ (23–32)	Z – Z (33–42)	
		1	20.0	0.0	0.0	(/)
		2	20.0	0.0	17.50	(/)
		3	20.0	0.0	35.00	(/)

FIGURE III-E.5 GRIDPOINT COORDINATES, THIN WALLED CYLINDER

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE - 0 - No Displacement Allowed
1 - Unknown Displacement
2 - Known Displacement

1	2	3	4	5	6	
B	O	U	N	D		(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	θx	θy	θz	1	2	3	
13	14	15	16	17	18	19	20	21	
1	0	1	0	1	0	1	0	1	(/)

LISTED INPUT

Grid Point Number					Repeat										
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
				1		0	0	0	0	0	0	0	0	0	(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
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															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)

FIGURE III-E.6 BOUNDARY CONDITIONS, THIN WALLED CYLINDER

RAC 1627

LOADS

LCOND	1	1.0	

Condition Number

Scalar

Transformation Code For Loads

MODAL

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERNAL LOADS

Grid Pt. Number	FORCE VALUES F_x	FORCE VALUES F_y	FORCE VALUES F_z	MOMENT VALUES M_x	MOMENT VALUES M_y	MOMENT VALUES M_z	GENERALIZED VALUES 1	GENERALIZED VALUES 2	GENERALIZED VALUES 3
3	1[illegible]95.4	0.0	0.0	0.0	-125676	0.0	0.0	0.0	0.0

FIGURE III-E.7 EXTERNAL LOADS, THIN WALLED CYLINDER

DAC 102R

ELEM (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER (7–10)	PLUG NO. (11–12)	MATERIAL NUMBER (13–18)	Interpolate Option (19)	MATERIAL TEMPERATURE (20–27)	Repeat Elem. Matrices (28)	Elem. Input (29)	PRINT: Print (30)	PRINT: Elem. Mat. (31)	PRINT: Full (32)	Number of Input Nodes (33–34)	Suppress Pressures (35)	NODE POINTS 1 (36–39)	2 (40–43)	3	4	5	6	7	8	9	10	11	12	
1	30	12				X			X	2		2	1											(/)
2	30	12				X				2		3	2											(/)

FIGURE III-E.8 ELEMENT CONTROL DATA, THIN WALLED CYLINDER

BAC 1629-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERN (/)

ELEMENT INPUT

Cols 1–6	A (13–22)	B (23–32)	C (33–42)	D (43–52)	E (53–62)	F (63–72)
MODAL	3.0	0.0	90.0	90.0		

Element Number (7–11)	Repeat (12)	A (13–22)	B (23–32)	C (33–42)	D (43–52)	E (53–62)	F (63–72)	
								(/
								(/
								(/
								(/
								(/
								(/
								(/
								(/
								(/
								(/
								(/
								(/
								(/
								(/
								(/
								(/

FIGURE III-E.9 ELEMENT INPUT, THIN WALLED CYLINDER

MAGIC STRUCTURAL ANALYSIS SYSTEM

INPUT DATA FORMAT

CHECK OR END CARD

C	H	E	C	K
1	2	3	4	5

(/)

E	N	D
1	2	3

(/)

FIGURE III-E.10 END CARD, THIN WALLED CYLINDER

The output supplied by the MAGIC System for the cylindrical shell subjected to edge loading is as follows:

Figures III-E.11 through III-E.15 display the output from the Structural System Monitor. These figures display the input data pertinent to the particular problem being solved.

Figure III-E.12 displays the coordinate and boundary condition information for this problem. In the Boundary Condition Section, note that there are 9 degrees of freedom per point for the toroidal ring element as follows:

$$u,\ o,\ w,\ o,\ \theta y,\ o,\ u',\ o,\ w''$$

The reader is referred to Section II.C-16.d of this report for a complete description of the meaning and significance of the above degrees of freedom.

In Figure III-E.13 the finite element information is displayed. Under the section External Input for Elements 1 and 2 the first entry printed is the element thickness of 3.00. The next entry printed is the control input, TCØ, which defines the axis of reference. In this case TCØ = 0.0 which causes the displacement behavior to be referenced to the Global System Axis. The next two entries printed are the quantities α_1 and α_2 respectively. These are defined as the angles measured in degrees from the axis of symmetry to a line which is perpendicular to the tangent to the surface at node points 1 and 2 respectively. Since this particular problem is a cylinder, $\alpha_1 = \alpha_2 = 90.0$ degrees.

MAGIC System output of final results is shown in Figures III-E.15 through III-E.

Figure III-E.15 shows the assembled and reduced stiffness matrix. The stiffness matrix is presented row-wise and only non-zero terms are displayed. The ordering of the stiffness matrix is consistent with that of the boundary conditions shown in Figure III-E.12. For this case the order of the displacement vector is as follows:

$$\{q\}^T = \lfloor u_2,\ w_2,\ u_2',\ w_2',\ w_2'',\ u_3,\ w_3,\ u_3',\ w_3',\ w_3 \rfloor$$

The externally applied loads for this application (GPRINT OF MATRIX LOADS) are presented in Figure III-E.16. The loads are listed against node point number. From the listed loads, it is seen that the first non-zero force corresponds to an applied force of 188500.0 acting in the R direction at node point 3, while the second is the applied moment of 125660.0 causing bending about the Y (θ) axis (MBETA). Note that the generalized forces (F_1, 0, and F_3) are all equal to 0.0.

Figure III-E.17 presents the displacements for this application. These displacements are output referenced to node point number and the Global Axis of Reference. (Unless otherwise indicated by the code TCØ = -1.0 in the Element Input Section.)

The Reactions are presented in Figure III-E.18. Note that they are listed according to node point number and have components (F_R, 0, F_Z, 0, M_β, 0, F_1, 0, F_3).

Figures III-E.19 and III-E.20 present the stresses for Toroidal Thin Shell Elements (1) and (2) respectively. In the toroidal ring element, stresses are evaluated at the two ends of the element as well as at the midspan of the element. Referring to Figure III-E.19, note that Stress Point 1 corresponds to Element Grid Point No. 2 while Stress Point 2 corresponds to Grid Point No. 1. Stress Point 3 corresponds to the element midspan position.

Five values of stress are displayed per point on each element, giving a total of 15 stresses per element.

The stress resultants for the toroidal ring are referenced to the element axes. The following are the stress resultants displayed for the toroidal ring element. (See sketches.)

$$T_\xi = \int_z \sigma_\xi \, dz \, ; \qquad \text{units, } \frac{\text{force}}{\text{length}}$$

$$T_\beta = \int_z \sigma_\beta \, dz \, ; \qquad \text{units, } \frac{\text{force}}{\text{length}}$$

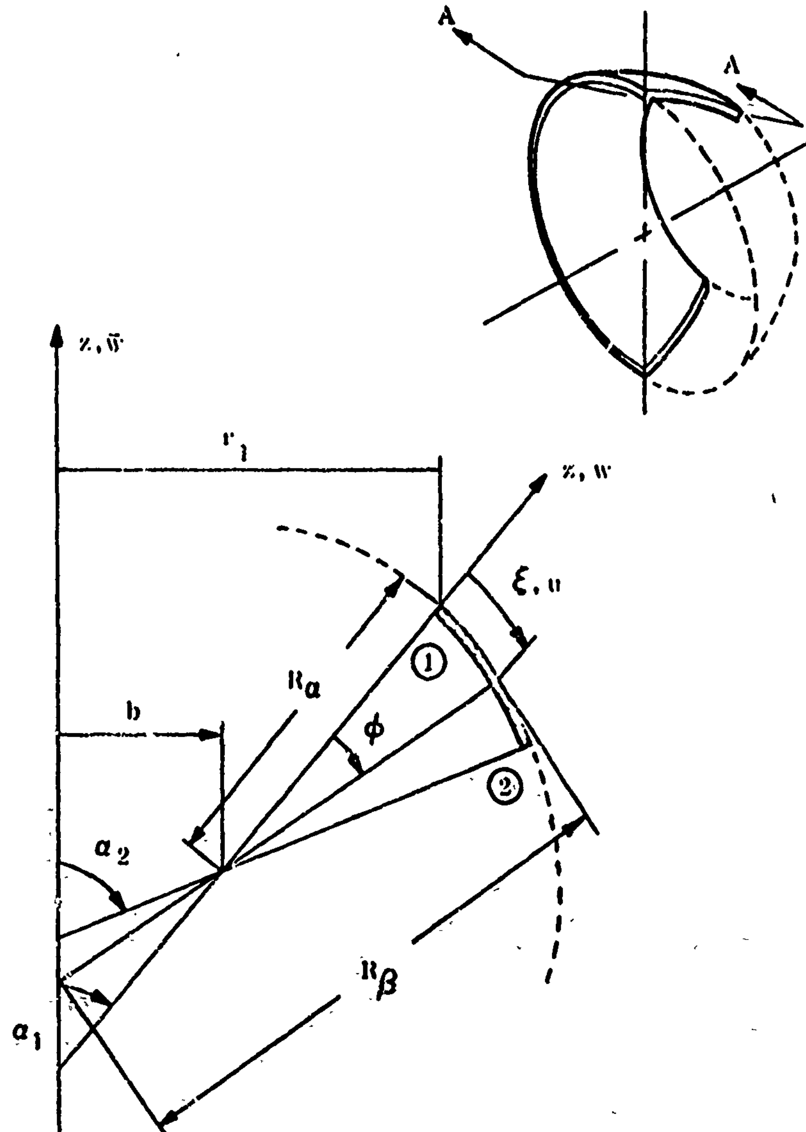
$$M_\beta = \int_z z \, \sigma_\xi \, dz \, ; \qquad \text{units, } \frac{(\text{force}) \times (\text{length})}{(\text{length})}$$

$$M_\xi = -\int_z z \, \sigma_\beta \, dz \, ; \qquad \text{units, } \frac{(\text{force}) \times (\text{length})}{(\text{length})}$$

$$Q_\xi = \lambda_2 \left[M_\beta + M_\xi \right] + \frac{\partial M_\beta}{\partial \xi} \qquad \text{units, } \frac{\text{force}}{\text{length}}$$

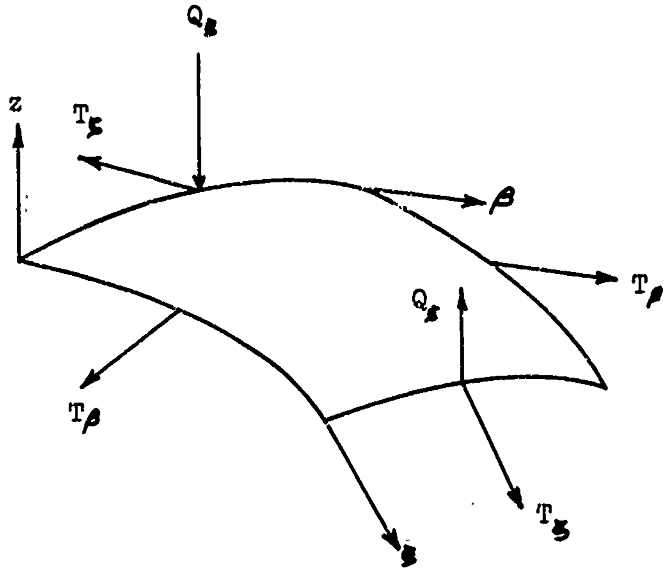
where $\lambda_2 = \frac{1}{B} \frac{\partial B}{\partial \xi}$

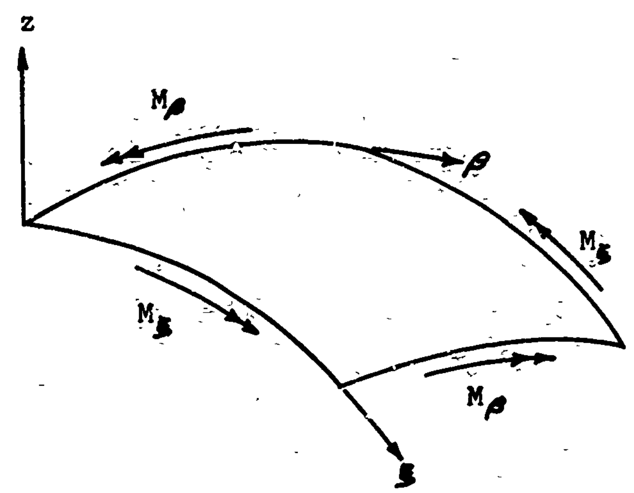
and B is a metric parameter which is explicitly defined in Volume I, Section 7, Equation 180.



Section A-A

Toroidal Thin Shell Ring Representation


Q_ξ
z
T_ξ
β
T_β
Q_ξ
T_β
T_ξ
ξ


z
M_β
β
M_ξ
M_ξ
M_β
ξ

The element forces are presented in Figures III-E.21 and III-E.22.

Nine forces are defined per node point which correspond to the nine displacement degrees of freedom per point, i.e.,

$$\left\{Disp\right\}^T = \lfloor u, o, w, o, \theta_y, o, u', o, w'' \rfloor$$

The interpretation of the forces is dependent upon the code TCØ which was used in the element input section. A code of TCØ = -1.0 references the displacement behavior and the force behavior to the element axes. A code of TCØ = 0.0 (which was used in this particular problem) references the displacement and force behavior to the Global System Axis. The ordering of the force output is as follows:

$$\left\{Force\right\}^T = \lfloor F_R, 0, F_Z, 0, M_\beta, 0, F_1, 0, F_3 \rfloor$$

where F_R is the force in the system radial direction

F_Z is the force in the system axial direction

M_β is the meriodional moment

F_1 and F_3 are the generalized forces corresponding to the u' and w" respectively

Note again that for this particular problem, the forces are referenced to the Global System Axes. If the Code TCØ = -1.0 would have been used the force behavior would have been referenced to the element axis and would have had the following form:

$$\left\{Force\right\}^T = \lfloor F_m, o, F_n, o, M, o, F_1, o, F_3 \rfloor$$

where F_m is the membrane force

F_n is the normal force

M_β is the meriodional moment

F_1 and F_3 are the generalized forces corresponding to the u' and w" respectively.

From Figure III-E.21 (Element No. 1) note that Force Point 1 corresponds to Grid Point 2 and Force Point 2 corresponds to Grid Point 1. In Figure III-E.22 (Element No. 2) Force Point 1 corresponds to Grid Point 3 and Force Point 2 corresponds to Grid Point 2.

```
CYLINDRICAL SHELL SUBJECTED TO END LOADINGS
TWO TOROIDAL RING ELEMENTS USED IN THE IDEALIZATION
REFERENCE- KLEIN,S. STUDY OF THE MATRIX DISPLACEMENT METHOD APPLIED
TO SHELLS OF REVOLUTION,CONFERENCE ON MATRIX METHODS IN STR. MECH.
WRIGHT-PATTERSON AFB, 1965

                    REVISIONS OF MATERIAL TAPE

                 ASTERISK (*) PRECEEDING MATERIAL
                 IDENTIFICATION INDICATES THAT INPUT
                 ERROR RETURNS WILL NOT RESULT IN
                    TERMINATION OF EXECUTION
*************************************************************************************
REVISION
  MATERIAL NUMBER       12
  MATERIAL IDENTIFICATION   E= 3.0E6, NU=0.30              INPUT CODE   1
    NUMBER OF MATERIAL PROPERTY POINTS. . . .  1
    NUMBER OF PLASTIC PROPERTY POINTS . . . . -0
    MASS DENSITY. . . . . . . . . . . . . . .-0.

  MATERIAL PROPERTIES
                      YOUNG'S MODULI                                POISSON'S RATIOS
                        DIRECTIONS                                     DIRECTIONS
TEMPERATURE
                  XX             YY             ZZ             XY             YZ             ZX
   0.       0.300000E 07   0.300000E 07   0.300000E 07   0.300000E 00   0.300000E 00   0.300000E 00
                THERMAL EXPANSION COEFFICIENTS                      RIGIDITY MODULI
                        DIRECTIONS                                     DIRECTIONS
TEMPERATURE
                  XX             YY             ZZ             XY             YZ             ZX
   0.       0.125000E-04   0.125000E-04   0.125000E-04   0.115385E 07   0.115385E 07   0.115385E 07
*************************************************************************************
```

FIGURE III-E.11 TITLE AND MATERIAL DATA OUTPUT, THIN WALLED CYLINDER

3 REF. POINTS

NO. DIRECTIONS = 3 NO. DEGREES OF FREEDOM = 3

GRIDPOINT DATA
(IN RECTANGULAR COORDINATES)

POINT	X	Y	Z	TEMPERATURES	PRESSURES
1	0.20000000E 02	0.0	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
2	0.20000000E 02	0.0	0.17500000E 02	0.0	0.0
				0.0	0.0
				0.0	0.0
3	0.20000000E 02	0.0	0.35000000E 02	0.0	0.0
				0.0	0.0
				0.0	0.0

BOUNDARY CONDITION INFORMATION

NODES	DEGREES OF FREEDOM									NO. OF ONES	NO. OF TWOS
1	0	0	0	0	0	0	0	0	0	0	0
2	1	0	1	0	1	0	1	0	1	5	0
3	1	0	1	0	1	0	1	0	1	10	0

FIGURE III-E.12 GRIDPOINT DATA AND BOUNDARY CONDITION OUTPUT, THIN WALLED CYLINDER

```
                                   TOTAL NO. ELEMENTS =      2

ELEM TYPE  PAT.NO. CODE  TEMP.   PRNT  NO.   --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  1  30       12    0 -0.          2    2      2   1

MATERIAL NUMBER. . . . . . . . .   12
    MATERIAL IDENTIFICATION. . . .    E= 30.0E6, MU=0.30
    ANALYSIS CAPABILITY. . . . . .      ISOTROPIC
    INPUT PRINT CODE . . . . . . .   1
    ELEMENT PRINT CODE . . . . . .  -1

INTERPOLATED MATERIAL PROPERTIES
    TEMPERATURE =        0.
    YOUNG'S MODULI                      0.30000000E 07     0.30000000E 07     0.30000000E 07
    POISSON'S RATIOS                    0.30000000E 00     0.30000000E 00     0.30000000E 00
    THERMAL EXPANSION COEFFICIENTS      0.12500000E-04     0.12500000E-04     0.12500000E-04
    RIGIDITY MODULI                     0.11538461E 07     0.11538461E 07     0.11538461E 07

INTERPOLATED PLASTIC PROPERTIES
    NONE

PRE-STRAIN INPUT
    NONE

PRE-STRESS INPUT
    NONE

EXTERNAL INPUT                                      0.90000000E 02     0.90000000E 02     -0.
          0.30000000E 01      0.

ELEM TYPE  PAT.NO. CODE  TEMP.   PRNT  NO.   --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  2  30       12    0  0.          0    2      3   2                                      0.3000E 01   0.            0.9000E 02
                                                                                          0.9000E 02  -0.
```

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FIGURE III-E.13 FINITE ELEMENT DESCRIPTION OUTPUT, THIN WALLED CYLINDER

```
                                   EXTERNAL LOAD CONDITIONS    1

 LOAD NO.   1

    NUMBER OF LOADED NODES     1          ELEMENT LOAD SCALAR =  0.
3  0.18850E 06  0.          0.          0.          0.12566E 06  0.          0.          0.          0.

                             TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN

                                            27 X 1
 0.                 0.                 0.                 0.                 0.                 0.
 0.                 0.                 0.                 0.                 0.                 0.
 0.                 0.                 0.                 0.                 0.                 0.
 0.18850000E 06     0.                 0.                 0.                 0.                 0.
 0.                 0.                 0.                                    0.12566000E 06     0.

                                  T-ZERO FOR STRUCTURE = -0.
```

FIGURE III-E.14 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, THIN WALLED CYLINDER

MATRIX STIFF PAGE 1

CUTOFF = C. SIZE 10 BY 10

		FORCE		FORCE		FORCE		FORCE		FORCE	
DISP.	1	1	0.465676E 08	2	-0.150000E 02	3	-0.125000E 03	4	0.699091E 08	5	0.214458E 09
		6	0.290304E 07	7	0.932122E 07	8	-0.501150E 07	9	-0.349546E 08	10	0.315374E 08
DISP.	2	1	-0.150000E 02	2	0.170445E 09	3	-0.792303E 08	4	0.450000E 02	5	-0.291000E 03
		6	-0.932120E 07	7	-0.852225E 08	8	0.396151E 08	9	0.124283E 09	10	-0.611702E 08
DISP.	3	1	-0.125000E 03	2	-0.792303E 08	3	0.108418E 10	4	-0.147656E 04	5	-0.241600E 04
		6	0.501169E 07	7	0.396152E 08	8	0.456509E 07	9	-0.129138E 09	10	0.166802E 09
DISP.	4	1	0.699091E 08	2	0.450000E 02	3	-0.147656E 04	4	0.579986E 10	5	-0.118941E 09
		6	-0.349545E 08	7	-0.124283E 09	8	0.129137E 09	9	-0.724983E 09	10	-0.178411E 09
DISP.	5	1	0.214450E 09	2	-0.291000E 03	3	-0.241600E 04	4	-0.118941E 09	5	0.390020E 10
		6	0.315375E 08	7	0.611705E 08	8	-0.166799E 09	9	-0.178415E 09	10	0.692953E 09
DISP.	6	1	0.290304E 07	2	-0.932120E 07	3	0.501169E 07	4	-0.349545E 08	5	0.315375E 08
		6	0.242838E 08	7	0.932120E 07	8	-0.901424E 08	9	0.349546E 08	10	0.107229E 09
DISP.	7	1	0.932122E 07	2	-0.852225E 08	3	0.396152E 08	4	-0.124283E 09	5	0.611705E 08
		6	0.932120E 07	7	0.852225E 06	8	-0.396151E 08	9	-0.124283E 09	10	0.611702E 08
DISP.	8	1	-0.501150E 07	2	0.396151E 08	3	0.456509E 07	4	0.129137E 09	5	-0.166799E 09
		6	-0.901424E 08	7	-0.396151E 08	8	0.542091E 09	9	-0.679777E 07	10	-0.655640E 09
DISP.	9	1	-0.349546E 08	2	0.124283E 09	3	-0.129138E 09	4	-0.724983E 09	5	-0.178415E 09
		6	0.349546E 08	7	-0.124283E 09	8	-0.679777E 07	9	0.289993E 10	10	-0.594693E 08
DISP.	10	1	0.315374E 08	2	-0.611702E 08	3	0.166802E 09	4	-0.178411E 09	5	0.692953E 09
		6	0.107229E 09	7	0.611702E 06	8	-0.655640E 09	9	-0.594693E 08	10	0.195011E 10

FIGURE III-E.15 REDUCED STIFFNESS MATRIX OUTPUT, THIN WALLED CYLINDER

GPPINT CF MATRIX LOADS (SET 1)

ROW	FR	0	FZ	C	MBETA	0
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.18850000E 06	0.0	0.0	0.0	-0.12566000E 06	0.0

GPRINT CF MATRIX LOADS (SET 1)

ROW	F1	0	F3
1	0.0	0.0	0.0
2	0.0	0.0	0.0
3	0.0	0.0	0.0

FIGURE III-E.16 LOAD OUTPUT, THIN WALLED CYLINDER

DISPLACEMENT MATRIX FOR LOAD CONDITION 1

27 X 1

ROW	U	0	W	C	THETAY	0
1	0.0	0.0	0.0	0.0	0.0	0.0
2	-0.10162622E-02	0.0	0.57556113E-04	0.0	[illegible]	0.0
3	0.19650411E-01	0.0	-0.98954258E-03	0.0	0.28519509E-02	0.0

DISPLACEMENT MATRIX FOR LOAD CONDITION 1

27 X 1

ROW	W*	0	W**
1	0.0	0.0	0.0
2	0.80076770E-05	0.0	0.36955767E-04
3	-0.28851372E-03	0.0	-0.865503642E-04

FIGURE III-E.17 DISPLACEMENT OUTPUT, THIN WALLED CYLINDER

REACTIONS AND INVERSE CHECK FOR LOAD CONDITION 1

ROW	FR	0	FZ		MBETA	0
1	-0.11091252E 04	0.0	-0.28076172E 03	0.0	0.19465977E 04	0.0
2	0.76660156E-01	0.0	-0.93750000E-01	0.0	0.40234375E 00	0.0
3	-0.25000000E 00	0.0	0.14062500E 00	0.0	0.16250000E 01	0.0

REACTIONS AND INVERSE CHECK FOR LOAD CONDITION 1

ROW	F1	C	F2
1	0.51955703E 04	0.0	0.95932930E 04
2	0.30117188E 01	0.0	0.33203125E 00
3	0.29687500E 00	0.0	0.62500000E-01

FIGURE III-E.18 REACTION OUTPUT, THIN WALLED CYLINDER

S T R E S S E S   F O R   T H E   T O R O I D A L   T H I N   S H E L L   E L E M E N T

(STRESS POINT TWO EQUALS ELEMENT STRESSES EVALUATED AT THE MID-POINT)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	30	2 1

APPARENT ELEMENT STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS TANGENTIAL	MEMBRANE STRESS RESULTANTS CIRCUMFERENTIAL	FLEXURAL MOMENTS TANGENTIAL	FLEXURAL MOMENTS CIRCUMFERENTIAL	SHEAR
1	-0.71567261E 02	-0.47878784E 03	-0.27412231E 03	0.82236633E 02	0.12933301E 03
2	0.13689346E 02	-0.42313217E 02	0.12157611E 03	-0.36472931E 02	-0.11611557E 02
3	-0.15679235E-02	-0.11109072E-02	0.19401992E-02	0.11158432E-02	0.11098816E 02

ELEMENT APPLIED STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS TANGENTIAL	MEMBRANE STRESS RESULTANTS CIRCUMFERENTIAL	FLEXURAL MOMENTS TANGENTIAL	FLEXURAL MOMENTS CIRCUMFERENTIAL	SHEAR
1	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS TANGENTIAL	MEMBRANE STRESS RESULTANTS CIRCUMFERENTIAL	FLEXURAL MOMENTS TANGENTIAL	FLEXURAL MOMENTS CIRCUMFERENTIAL	SHEAR
1	-0.71567261E 02	-0.47678784E 03	-0.27412231E 03	0.82236633E 02	0.12933301E 03
2	0.13689346E 02	-0.42313217E 02	0.12157611E 03	-0.36472931E 02	-0.11611557E 02
3	-0.15679235E-02	-0.11109072E-02	0.19401992E-02	0.11158432E-02	0.11098816E 02

FIGURE III-E.19 STRESS OUTPUT, ELEMENT NO. 1. THIN WALLED CYLINDER

S T R E S S E S   F O R   T H E   T O R O I D A L   T H I N   S H E L L   E L E M E N T

(STRESS POINT TWO EQUALS ELEMENT STRESSES EVALUATED AT THE MID-POINT)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	2	30	3 2

APPARENT ELEMENT STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS TANGENTIAL	MEMBRANE STRESS RESULTANTS CIRCUMFERENTIAL	FLEXURAL MOMENTS TANGENTIAL	FLEXURAL MOMENTS CIRCUMFERENTIAL	SHEAR
1	0.61736572E 02	0.88611953E 04	0.64164746E 03	-0.19249446E 03	-0.10990171E 04
2	-0.37804626E 02	0.46274731E 03	-0.19581636E 04	0.58744625E 03	0.22621983E 03
3	-0.71554245E 02	-0.47883350E 03	-0.27410840E 03	0.82208267E 02	-0.11984344E 03

ELEMENT APPLIED STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS TANGENTIAL	MEMBRANE STRESS RESULTANTS CIRCUMFERENTIAL	FLEXURAL MOMENTS TANGENTIAL	FLEXURAL MOMENTS CIRCUMFERENTIAL	SHEAR
1	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS TANGENTIAL	MEMBRANE STRESS RESULTANTS CIRCUMFERENTIAL	FLEXURAL MOMENTS TANGENTIAL	FLEXURAL MOMENTS CIRCUMFERENTIAL	SHEAR
1	0.61736572E 02	0.88611953E 04	0.64164746E 03	-0.19249446E 03	-0.10990171E 04
2	-0.37804626E 02	0.46274731E 03	-0.19581636E 04	0.58744625E 03	0.22621983E 03
3	-0.71554245E 02	-0.47883350E 03	-0.27410840E 03	0.82208267E 02	-0.11984344E 03

FIGURE III-E.20 STRESS OUTPUT, ELEMENT NO. 2 THIN WALLED CYLINDER

F O R C E S   F O R   T H E   T O R O I D A L   T H I N   S H E L L   E L E M E N T

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	30	1 2

APPARENT ELEMENT FORCES

POINT	FORCES RADIAL (FR)	FORCES CIRCUM. (F-THETA)	FORCES AXIAL (FZ)	MOMENTS RADIAL	MOMENTS MERIDIONAL (M-BETA)	MOMENTS AXIAL	GENERALIZED FORCES (F1) (DIRECT STRAIN)	GENERALIZED FORCES (F2)	GENERALIZED FORCES (F3) (CURVATURE)
1	-0.123787E 05	0.0	0.284277E 01	0.0	0.198204E 05	0.0	-0.210850E 05	0.0	0.208366E 05
2	-0.110913E 04	0.0	-0.280762E 01	0.0	0.194660E 04	0.0	0.519657E 04	0.0	0.959329E 04

ELEMENT APPLIED FORCES

POINT	FORCES RADIAL (FR)	FORCES CIRCUM. (F-THETA)	FORCES AXIAL (FZ)	MOMENTS RADIAL	MOMENTS MERIDIONAL (M-BETA)	MOMENTS AXIAL	GENERALIZED FORCES (F1) (DIRECT STRAIN)	GENERALIZED FORCES (F2)	GENERALIZED FORCES (F3) (CURVATURE)
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT FORCES

POINT	FORCES RADIAL (FR)	FORCES CIRCUM. (F-THETA)	FORCES AXIAL (FZ)	MOMENTS RADIAL	MOMENTS MERIDIONAL (M-BETA)	MOMENTS AXIAL	GENERALIZED FORCES (F1) (DIRECT STRAIN)	GENERALIZED FORCES (F2)	GENERALIZED FORCES (F3) (CURVATURE)
1	-0.123787E 05	0.0	0.284277E 01	0.0	0.198204E 05	0.0	-0.210850E 05	0.0	0.208366E 05
2	-0.110913E 04	0.0	-0.280762E 01	0.0	0.194660E 04	0.0	0.519657E 04	0.0	0.959329E 04

FIGURE III-E.21 FORCE OUTPUT, ELEMENT NO. 1, THIN WALLED CYLINDER

F O R C E S   F O R   T H E   T O R O I D A L   T H I N   S H E L L   E L E M E N T

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	2	30	1 2

APPARENT ELEMENT FORCES

POINT	FORCES RADIAL (FR)	FORCES CIRCUM. (F-THETA)	FORCES AXIAL (FZ)	MOMENTS RADIAL	MOMENTS MERIDIONAL (M-BETA)	MOMENTS AXIAL	GENERALIZED FORCES (F1) (DIRECT STRAIN)	GENERALIZED FORCES (F2)	GENERALIZED FORCES (F3) (CURVATURE)
1	C.18E5COE C6	0.0	0.142334E 00	0.0	-0.125659E 06	0.0	C.3164C6E C0	0.0	0.179683E 00
2	0.123788E 05	0.0	-0.295483E 01	0.0	-0.198205E 05	0.0	C.210878E 05	0.0	-0.208363E 05

ELEMENT APPLIED FORCES

POINT	FORCES RADIAL (FR)	FORCES CIRCUM. (F-THETA)	FORCES AXIAL (FZ)	MOMENTS RADIAL	MOMENTS MERIDIONAL (M-BETA)	MOMENTS AXIAL	GENERALIZED FORCES (F1) (DIRECT STRAIN)	GENERALIZED FORCES (F2)	GENERALIZED FORCES (F3) (CURVATURE)
1	C.C	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0
2	C.0	0.0	0.0	0.0	0.0	0.0	0.C	0.0	0.0

NET ELEMENT FORCES

POINT	FORCES RADIAL (FR)	FORCES CIRCUM. (F-THETA)	FORCES AXIAL (FZ)	MOMENTS RADIAL	MOMENTS MERIDIONAL (M-BETA)	MOMENTS AXIAL	GENERALIZED FORCES (F1) (DIRECT STRAIN)	GENERALIZED FORCES (F2)	GENERALIZED FORCES (F3) (CURVATURE)
1	C.18E5COE 06	0.0	0.142334E 00	0.0	-0.125659E 06	0.0	C.3164C6E 00	0.0	0.179688E 00
2	C.123788E C5	0.0	-0.295483E 01	0.0	-0.198205E 05	0.0	0.210878E 05	0.0	-0.208363E 05

FIGURE III-E.22 FORCE OUTPUT, ELEMENT NO. 2, THIN WALLED CYLINDER

F. SQUARE PLATE - PARABOLIC MEMBRANE LOADING (Quadrilateral Thin Shell Idealization)

An isotropic, square plate under the action of a parabolic membrane loading is shown in Figure III-F.1, along with its dimensions and pertinent material properties. The plate is idealized utilizing one quadrilateral thin shell element.

The preprinted input data forms associated with this example are shown in Figures III-F.2 through III-F.10.

In Figure III-F.5 (Grid Point Coordinate Section) it can be seen that only the grid point coordinates for the four corner points of the element are entered. The coordinates associated with mid-point nodes are calculated internally by the MAGIC System.

In Figure III-F.6 (Boundary Condition Section) it is instructive to note the extensive use of the Repeat option. Grid point 5 has identical boundary conditions as grid point 2, therefore the Repeat option is exercised by placing an 'X' in column 12 opposite the entry for Grid Point Number 5. The same procedure is also used for Grid Points 3, and 7 as well as for Grid Points 4 and 8. (MODAL entry pertains to Grid Point 1 and to Grid Point 6 which is suppressed).

In Figure III-F.7 (External Loads Section) Grid Points 2 and 3 have applied external loading. Note that there are 2 external load cards per grid point.

In Figure III-F.8 (Element Control Data Section) the following information is of importance.

(1) Mid-point node number 6 is suppressed. The element is therefore numbered 1, 2, 3, 4, 5, 0, 7, 8. These entries are made in the first eight locations of the node point section as shown in Figure III-F.8.

(2) The numbers '1' and '2' are entered in locations 9 and 10 of the node point portion of the Element Control Section. These two points define the X direction for the material properties axes. This allows the User to effectively define stress output direction. The same two points used for the reference element can also be used for each following element (if they exist) so that the output has a common reference.

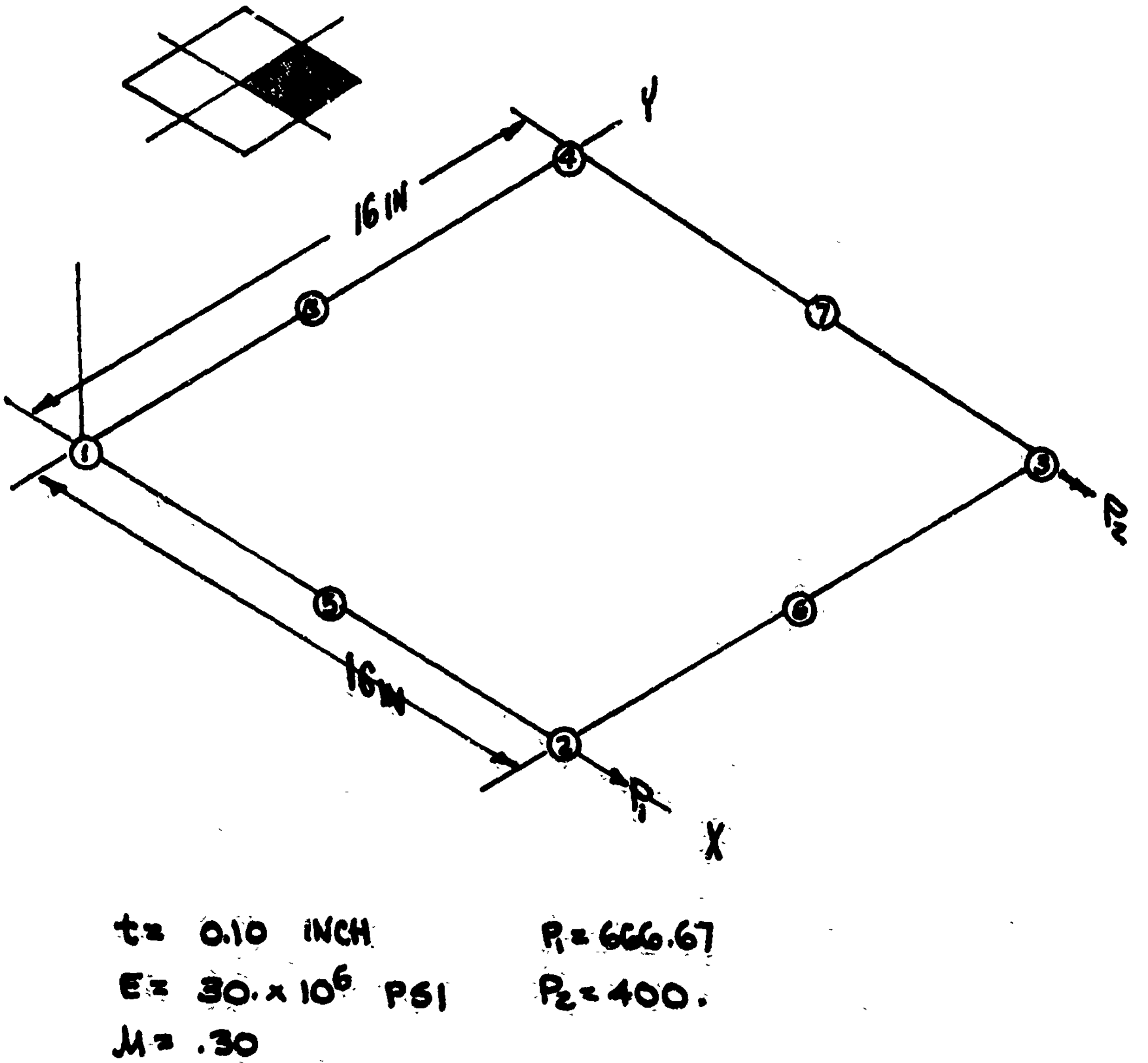

FIGURE III - P.1 - Idealized Square Plate With Parabolic Membrane Loading (Quadrilateral Thin Shell Idealization)

In Figure III-F.9 (Element Input Section) only one item of information is entered in Location A as follows:

Location A - Membrane Thickness - (t_m) = 0.10

BAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

REPORT (/)

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

1 2 3 4 5 6

TITLE (/)

7 8 9

6 (/) NUMBER OF TITLE CARDS

QUADRILATERAL SIMPLY SUPPORTED THIN PLATE SUBJECTED TO A SELF- (/

EQUILIBRATING PARABOLIC MEMBRANE LOADING - ONE QUADRILATERAL (/

THIN SHELL ELEMENT USED IN THE IDEALIZATION, MIDPOINT NODE ON (/

THE LOADED SIDE IS SUPPRESSED IN THIS ANALYSIS (/

REFERENCE - TIMOSHENKO, S. AND GOODIER, J.N. THEORY OF ELASTICITY SECOND (/

EDITION, MC GRAW HILL, NEW YORK, 1951. (/

(/)

(/

(/)

FIGURE III-F.2 TITLE INFORMATION, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

BAC 1616-1

MATER (/)
1 2 3 4 5 5

1 (/)
7 8 9
No. of Requests

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MATERIAL TAPE INPUT

Request Number	MATERIAL NUMBER	Lock Code	MATERIAL IDENTIFICATION	Isotropic	Orthotropic	Plastic Isotropic	Plastic Orthotropic	Add Plastic	Delete Material	Print Tape	Print Mat'l. Table	Print Mat'l. Summary	Number of Mat'l. Pts.	Number of Plastic Pts.	MASS DENSITY	
7–9	10–15	16–17	18–41	42	43	44	45	46	47	48	49	50	51–52	53–54	55–64	
1	12	TU	STEEL-E=30.0E6, MU=0.30	X							X		1		0.0005	(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE (13–22)	Direction	YOUNGS MODULI (23–32)	Direction	POISSONS RATIOS (33–42)	Direction	COEF. OF THERMAL EXPANSION (43–52)	Direction	RIGIDITY MODULI (53–62)	
0.0	E_x	30.0 E6	ν_{xy}	0.30	α_x	8.50 E-6	G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

FIGURE III-F.3 MATERIAL TAPE INPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

> ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

Request	Entry	Columns
	S Y S T E M (/)	1 2 3 4 5 6
1. Number of System Grid Points	8	1 2 3 4 5 6
2. Number of Input Grid Points	4	7 8 9 10 11 12
3. Number of Degrees of Freedom/Grid Point	6	13 14
4. Number of Load Conditions	1	15 16
5. Number of Initially Displaced Grid Points		17 18 19 20 21 22
6. Number of Prescribed Displaced Grid Points		23 24 25 26 27 28
7. Number of Grid Point Axes Transformation Systems		29 30
8. Number of Elements	1	31 32 33 34 35 36
9. Number of Requests and/or Revisions of Material Tape.	1	37 38
10. Number of Input Boundary Condition Points	6	39 40 41 42 43 44
11. T_o For Structure (With Decimal Point)	0.0 (/)	45 46 47 48 49 50 51 52

FIGURE III-F.4 SYSTEM CONTROL INFORMATION, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1 2 3 4 5 6
C O O R D (/)

GRIDPOINT COORDINATE

COORD. INPUT	$
RECTANGULAR	R/Δ
CYLINDRICAL	C
SPHERICAL	S

SYSTEM

Δ = BLANK

$	Grid Point Number	DIRECTIONS X – R	DIRECTIONS Y – θ	DIRECTIONS Z – Z	
5 6	7 8 9 10 1 2	13 4 5 6 7 8 9 20 1 2	23 4 5 6 7 8 9 30 1 2	33 4 5 6 7 8 9 40 1 2	
	1	0.0	0.0	0.0	(/)
	2	16.0	0.0	0.0	(/)
	3	16.0	16.0	0.0	(/)
	4	0.0	16.0	0.0	(/)

FIGURE III-F.5 GRIDPOINT COORDINATES, SQUARE PLATE
(QUADRILATERAL THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE - 0 - No Displacement Allowed
1 - Unknown Displacement
2 - Known Displacement

1	2	3	4	5	6
B	O	U	N	D	

(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	.

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	θx	θy	θz	1	2	3	
13	14	15	16	17	18	19	20	21	
0	0	0	0	0	0				(/)

LISTED INPUT

Grid Point Number 7-11	Repeat 12	13	14	15	16	17	18	19	20	21	
2		1	0	0	0	0	0				(/)
5	X										(/)
3		1	1	0	0	0	0				(/)
7	X										(/)
4		0	1	0	0	0	0				(/)
8	X										(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)

FIGURE III-F.6 BOUNDARY CONDITIONS, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

SAC 1527

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

LOADS (1)

LCOND — Condition Number — Scalar: 0.0 — Transformation Code For Loads (1)

MODAL

EXTERNAL LOADS

Grid Pt. Number	FORCE VALUES F_x	FORCE VALUES F_y	FORCE VALUES F_z	MOMENT VALUES M_x	MOMENT VALUES M_y	MOMENT VALUES M_z	GENERALIZED VALUES 1	GENERALIZED VALUES 2	GENERALIZED VALUES 3
2	667.67	0.0	0.0	0.0	0.0	0.0			
3	400.00	0.0	0.0	0.0	0.0	0.0			

FIGURE III-F.7 EXTERNAL LOADS, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

E	L	E	M		
1	2	3	4	5	6

(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER (7-10)	PLUG NO. (11-12)	MATERIAL NUMBER (13-18)	Interpolate Option (19)	MATERIAL TEMPERATURE (20-27)	Repeat Elem. Matrices (28)	Elem. Input (29)	PRINT: Print (30)	PRINT: Elem. Mat. (31)	PRINT: Full (32)	Number of Input Nodes (33-34)	Suppress Pressures (35)	NODE POINTS 1 (36-40)	2 (41-45)	3 (46-50)	4 (51-55)	5 (56-60)	6 (61-65)	7 (66-70)	8 (71-75)	9 (76-80)	10 (81-85)	11	12	
1	31	12				X			X	8		1	2	3	4	5	6	7	8	1	2			(/)

FIGURE III-F.8 ELEMENT CONTROL DATA, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

BAC 1628-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT INPUT

1	2	3	4	5	6	
E	X	T	E	R	N	(/)

1	2	3	4	5	6
M	O	D	A	L	

Element Number (7–11)	Repeat (12)	A (13–22)	B (23–32)	C (33–42)	D (43–52)	E (53–62)	F (63–72)	
1		0./0	0.0	0.0	0.0	0.0		(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
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								(/)
								(/)

FIGURE III-F.9 ELEMENT INPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM

INPUT DATA FORMAT

CHECK OR END CARD

C	H	E	C	K	(/)
1	2	3	4	5	

E	N	D	(/)
1	2	3	

FIGURE III-F.10 END CARD, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

The output supplied by the MAGIC System for the thin square plate subjected to parabolic loading and idealized with one quadrilateral thin shell element is as follows:

Figures III-F.11 thru III-F.13 display the output from the Structural Systems Monitor. These figures record the input data pertinent to the problem being solved.

In Figure III-F.12, the finite element information is shown. Under the section titled External Input, the first entry printed has a numerical value of 0.0999999. This value is equal to the membrane thickness of the plate being analyzed.

Figure III-F.13 displays the External Load Column for this problem. The 48 x 1 vector shown in the figure is the total unreduced transformed external load column which is read row-wise. The ordering is consistent with that of the boundary condition information shown in Figure III-F.12. An external load of 667.67 is applied at node point 2 and also a load of 400.0 is applied at note point 3, both in the positive Global X direction

MAGIC System output of final results is shown in Figures III-F.14 thru III-F.19. Figure III-F.14 shows the reduced stiffness matrix for this problem. Only non-zero terms in the stiffness matrix are displayed. The stiffness matrix is presented row-wise and its ordering is consistent with that of the boundary conditions shown in Figure III-F.12. For this case, the ordering of the displacement vector is as follows:

$$\left\{q\right\}^T = \lfloor u_2, u_3, v_3, v_4, u_5, u_7, v_7, v_8 \rfloor$$

The externally applied loads for this application (GPRINT OF MATRIX LOADS) are presented in Figure III-F.15. The loads are listed against node point number. It is to be noted that node points 2 and 3 have forces (F_X) equal in numerical value to 667.67 and 400.0 respectively. Both of these forces are acting in the positive Global X direction.

Figure III-F.16 presents the displacements for this application. These displacements are output referenced to node point number and the Global Axis of reference.

The Reactions are presented in Figure III-F.17. Note that they are listed according to node point number and have components R_X and R_Y.

Figure III-F.18 presents the stresses for the Quadrilateral Thin Shell Element. Eight stress resultants are evaluated at each corner point of the element and also at the intersection of the diagonals which connect the opposite corner points of the element. The stress resultants are defined as follows:

$$N_x = \int_x \sigma_x \, d\, z \qquad ; \text{ units } \frac{\text{force}}{\text{length}}$$

$$N_y = \int_z \sigma_y \, d\, z \qquad ; \text{ units } \frac{\text{force}}{\text{length}}$$

$$N_{xy} = \int_z \tau_{xy} \, d\, z \qquad ; \text{ units } \frac{\text{force}}{\text{length}}$$

$$M_x = \int_z z\, \sigma_x \, d\, z \qquad ; \text{ units } \frac{\text{force x length}}{\text{length}}$$

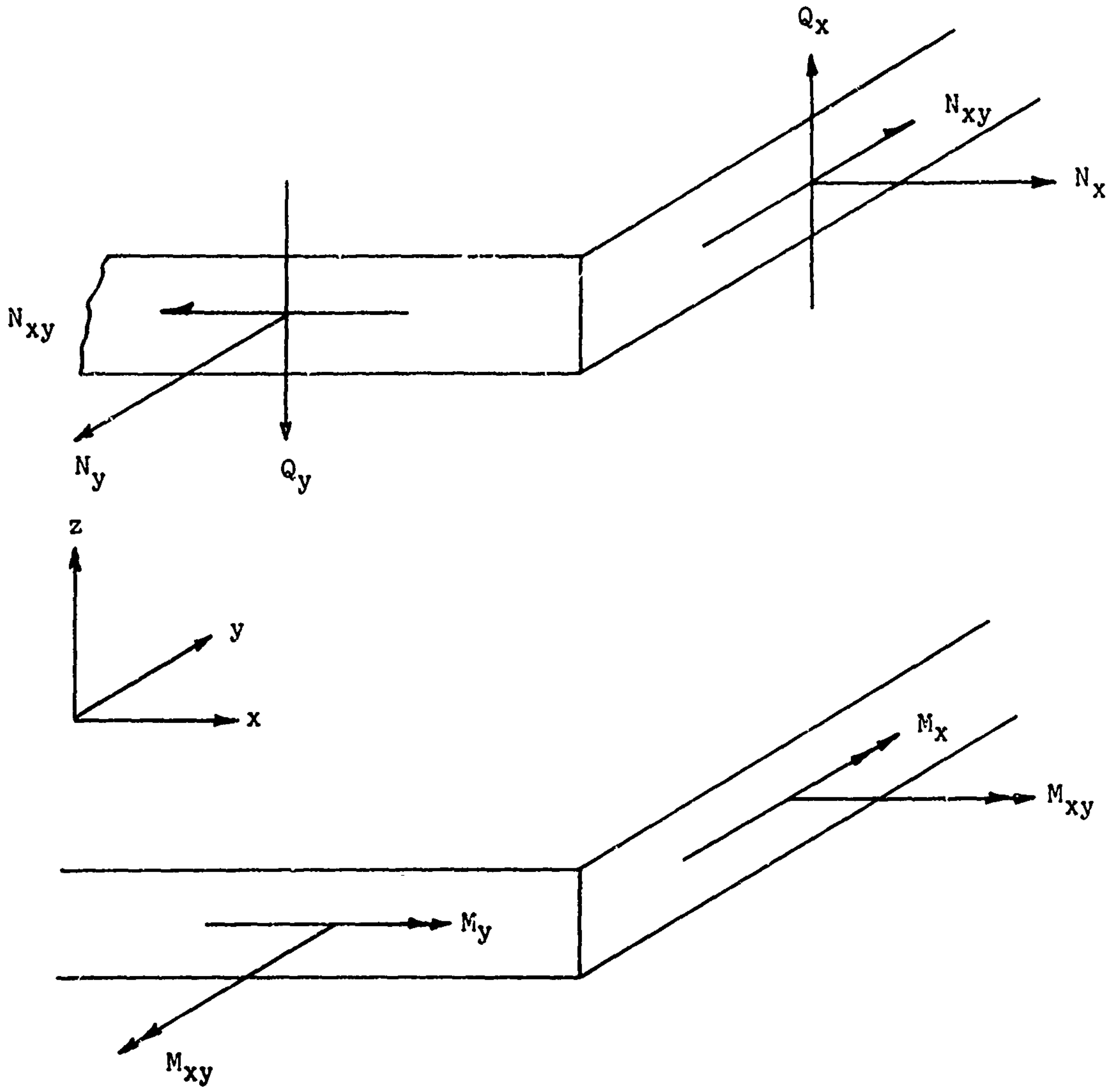
$$M_y = \int_z z\, \sigma_y \, d\, z \qquad ; \text{ units } \frac{\text{force x length}}{\text{length}}$$

$$M_{xy} = \int_z z\, \tau_{xy} \, d\, z \qquad ; \text{ units } \frac{\text{force x length}}{\text{length}}$$

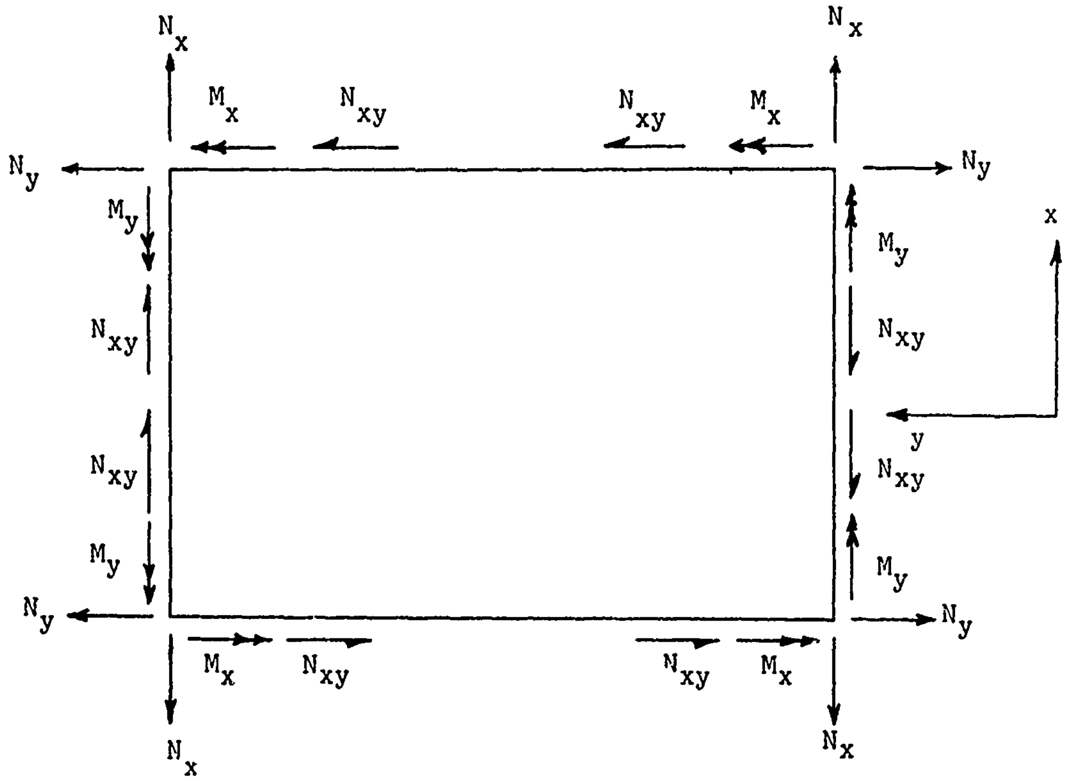
$$Q_x = \int_z z \left(\frac{\partial \sigma_x}{\partial x}\right) d\, z + \int_z z \left(\frac{\partial \tau_{xy}}{\partial y}\right) dz ; \text{ units } \frac{\text{force}}{\text{length}}$$

$$Q_y = \int_z z \left(\frac{\partial \sigma_y}{\partial y}\right) d\, z + \int_z z \left(\frac{\partial \tau_{xy}}{\partial x}\right) dz \; ; \text{ units } \frac{\text{force}}{\text{length}}$$

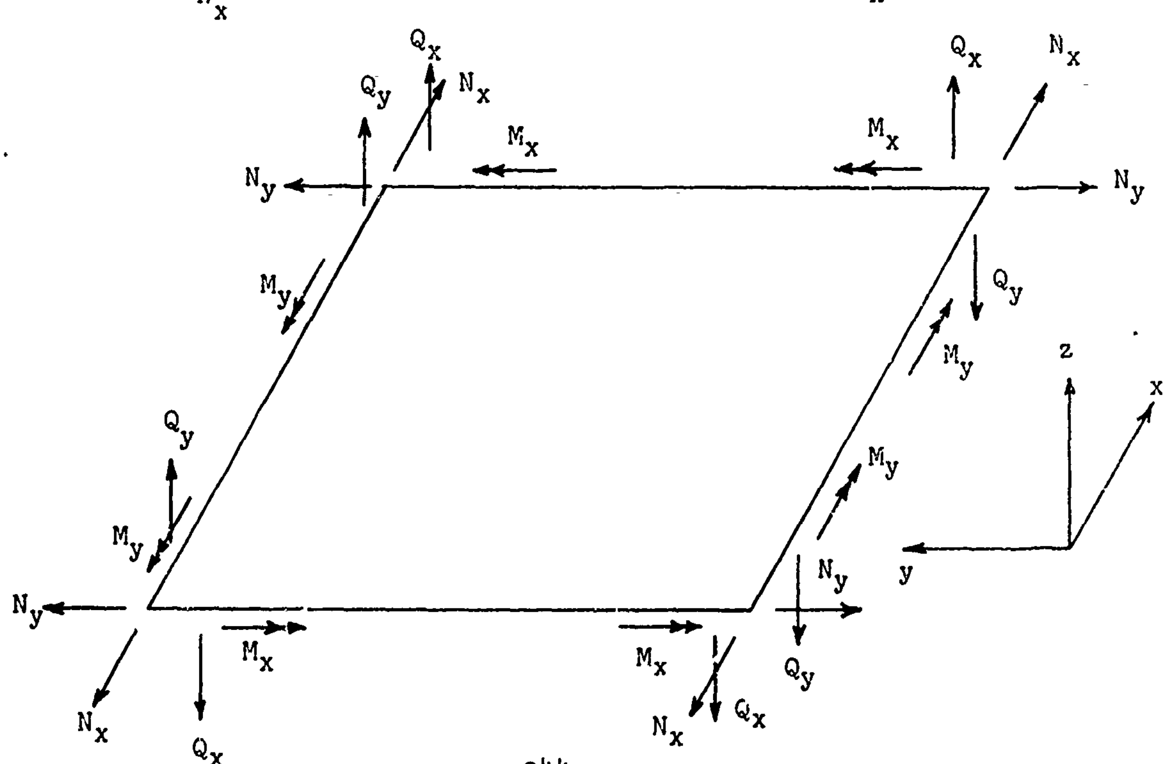
The following sketches show the proper manner in which to interpret the stress resultants.



Stress Resultants



N x
M x
N xy
N y
M y
x
y



Q x
Q y
N x
M x
N y
M y
z
x
y

Returning to Figure III-F.18, it is noted that there are five stress points at which the stress resultants are evaluated. These correspond to element grid points 1, 2, 3, and 4. The fifth stress point corresponds to the stresses evaluated at the element centroid. The stresses are in general referenced to the element coordinate system. For the quadrilateral or triangular thin shell elements, however, the User has the option of specifying material or stress axes in order to effectively define stress output direction. This is accomplished by utilizing locations 9 and 10 or 11 and 12 of the node point portion of the Element Control Section. In this particular problem the numbers '1' and '2' were entered in locations 9 and 10 of the node point portion of the Element Control Section. These two points define the X direction of the material properties axes. (Positive X from node point 1 to node point 2.) This axis of reference then becomes the reference axis for the stress output.

The element forces for the Quadrilateral Thin Shell Element are displayed in Figure III-F.19. The forces (F_X, F_Y, F_Z, M_X, M_Y, M_Z) are defined with respect to the Global Coordinate System. The forces are defined at eight points on the element. The first four points are corner points (Element Grid Points 1, 2, 3, and 4), and the last four points are mid-points (Element Grid Points 5, 0, 7, 8). Note that one of the mid-side nodes was suppressed in this analysis, corresponding to would-be grid point 6; therefore, there are no element forces evaluated at this particular point.

```
THIN SQUARE ISOTROPIC PLATE  SUBJECTED TO A SELF
EQUILIBRATING PARABOLIC MEMBRANE LOADING-ONE QUADRILATERAL
THIN SHELL ELEMENT USED IN THE IDEALIZATION,MIDPOINT NODE  ON
THE LOADED EDGE IS SUPPRESSED IN THIS ANALYSIS
REFERENCE- TIMOSHENKO,S. AND GOODIER,J.N., THEORY OF ELASTICITY,
SECOND EDITION,MCGRAW HILL NEW YORK 1951.

                         REVISIONS OF MATERIAL TAPE

                      ASTERISK (*) PRECEEDING MATERIAL
                      IDENTIFICATION INDICATES THAT INPUT
                      ERROR RETURNS WILL NOT RESULT IN
                          TERMINATION OF EXECUTION

****************************************************************************************
 REVISION
   MATERIAL NUMBER       12
   MATERIAL IDENTIFICATION     STEEL                          INPUT CODE   1
    NUMBER OF MATERIAL PROPERTY POINTS. . . .  1
    NUMBER OF PLASTIC PROPERTY POINTS . . . . -0
    MASS DENSITY. . . . . . . . . . . . . . .-0.

   MATERIAL PROPERTIES

                          YOUNG'S MODULI                                   POISSON'S RATIOS
                           DIRECTIONS                                        DIRECTIONS
TEMPERATURE
                 XX               YY               ZZ               XY               YZ               ZX
   0.      0.300000E 08     0.300000E 08     0.300000E 08     0.300000E 00     0.300000E 00     0.300000E 00
                    THERMAL EXPANSION COEFFICIENTS                                 RIGIDITY MODULI
                           DIRECTIONS                                        DIRECTIONS
TEMPERATURE
                 XX               YY               ZZ               XY               YZ               ZX
   0.      -0.              -0.              -0.              0.115385E 08     0.115385E 08     0.115385E 08
****************************************************************************************
```


FIGURE III-F.11 TITLE AND MATERIAL DATA OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

8 REF. POINTS

NO. DIRECTIONS = 3   NO. DEGREES OF FREEDOM = 2

GRIDPOINT DATA
(IN RECTANGULAR COORDINATES)

POINT	X	Y	Z
1	0.0	0.0	0.0
2	0.16000000E 02	0.0	0.0
3	0.16000000E 02	0.16000000E 02	0.0
4	0.0	0.16000000E 02	0.0

TEMPERATURES	PRESSURES
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0
0.0	0.0

BOUNDARY CONDITION INFORMATION

NODES	DEGREES OF FREEDOM						NO. OF ONES	NO. OF TWOS
1	0	0	0	0	0	0	0	0
2	1	0	0	0	0	0	1	0
3	1	1	0	0	0	0	3	0
4	0	1	0	0	0	0	4	0
5	1	0	0	0	0	0	5	0
6	0	0	0	0	0	0	5	0
7	1	1	0	0	0	0	7	0
8	0	1	0	0	0	0	8	0

FIGURE III-F.12 GRIDPOINT DATA, BOUNDARY CONDITION AND FINITE ELEMENT DESCRIPTION OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

```
                                   TOTAL NO. ELEMENTS =       1

ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NO.    --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  1  21       12    0  0.0          2    8     1  2  3  4  5  6  7  8         1  2

MATERIAL NUMBER. . . . . . . . .    12
     MATERIAL IDENTIFICATION. . . .   STEEL
     ANALYSIS CAPABILITY. . . . . .  ISOTROPIC
     INPUT PRINT CODE . . . . . . . . 1
     ELEMENT PRINT CODE . . . . . . .-1



INTERPOLATED MATERIAL PROPERTIES
     TEMPERATURE -       0.0
     YOUNG'S MODULI        0.30000000E 08      0.30000000E 08      0.30000000E 08
     POISSON'S RATIO       0.29999995E 00      0.29999995E 00      0.29999995E 00
     TH. EXP. COEF.        0.0                 0.0                 0.0
     RIGIDITY MODULI       0.11538468E 08      0.11538468E 08      0.11538468E 08

INTERPOLATED PLASTIC PROPERTIES
     NONE

PRE-STRAIN INPUT
     NONE

PRE-STRESS INPUT
     NONE

EXTERNAL INPUT
          0.99999994E-01      0.0            0.0            0.0            0.0
```

FIGURE III-F.12 GRIDPOINT DATA, BOUNDARY CONDITION AND FINITE ELEMENT DESCRIPTION OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION) (CONTINUED)

```
                              EXTERNAL LOAD CONDITIONS   1

   LOAD NC.   1
     NUMBER OF LOADED NODES    2         ELEMENT LOAD SCALAR =  0.
2  0.66767E 03  0.          0.          0.          0.          0.
3  0.40000E 03  0.          0.          0.          0.          0.

                         TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN
                                        48 X 1
   0.                0.          0.          0.          0.          0.
   0.66767000E 03    0.          0.          0.          0.          0.
   0.40000000E 03    0.          0.          0.          0.          0.
   0.                0.          0.          0.          0.          0.
   0.                0.          0.          0.          0.          0.
   0.                0.          0.          0.          0.          0.
   0.                0.          0.          0.          0.          0.
   0.                0.          0.          0.          0.          0.

                              T-ZERO FOR STRUCTURE =  0.
```

FIGURE III-F.13 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

MATRIX STIFF PAGE 1

CUTOFF = 0. SIZE 8 BY 8

		FORCE		FORCE		FORCE		FORCE		FORCE	
DISP.	1	1	0.293956E 07	2	0.906593E 06	3	-0.412088E 05	4	-0.178571E 06	5	-0.329670E 07
		6	-0.109890E 07	7	0.714286E 06	8	0.585938E-01				
DISP.	2	1	0.906593E 06	2	0.293956E 07	3	0.535714E 06	4	0.137362E 05	5	-0.109890E 07
		6	-0.329670E 07	7	-0.549451E 05	8	0.273438E-01				
DISP.	3	1	-0.412088E 05	2	0.535714E 06	3	0.151099E 07	4	0.384615E 06	5	-0.714286E 06
		6	0.549450E 05	7	-0.115385E 07	8	-0.384615E 06				
DISP.	4	1	-0.178571E 06	2	0.137362E 05	3	0.384615E 06	4	0.296703E 07	5	0.234375E-01
		6	0.659341E 06	7	-0.115385E 07	8	-0.329670E 07				
DISP.	5	1	-0.329670E 07	2	-0.109890E 07	3	-0.714286E 06	4	0.234375E-01	5	0.736264E 07
		6	0.142857E 07	7	-0.101563E 00	8	0.142857E 07				
DISP.	6	1	-0.109890E 07	2	-0.329670E 07	3	0.549450E 05	4	0.659341E 06	5	0.142857E 07
		6	0.736264E 07	7	0.156250E 00	8	-0.142857E 07				
DISP.	7	1	0.714286E 06	2	-0.549451E 05	3	-0.115385E 07	4	-0.115385E 07	5	-0.101563E 00
		6	0.156250E 00	7	0.450549E 07	8	0.109375E 00				
DISP.	8	1	0.585938E-01	2	0.273438E-01	3	-0.384615E 06	4	-0.329670E 07	5	0.142857E 07
		6	-0.142857E 07	7	0.109375E 00	8	0.736264E 07				

FIGURE III-F.14 REDUCED STIFFNESS MATRIX OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

GPRINT OF MATRIX LOADS (SET 1)

ROW	FX	FY	FZ	MX	MY	MZ
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.667669992E 03	0.0	0.0	0.0	0.0	0.0
3	0.400000000E 03	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE III-F.15 LOAD OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

DISPLACEMENT MATRIX FOR LOAD CONDITION 1

48 X 1

ROW	U	V	W	THETAX	THETAY	THETAZ
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.510387599E-03	0.0	0.0	0.0	0.0	0.0
3	0.201390195E-03	-0.212343591E-04	0.0	0.0	0.0	0.0
4	0.0	-0.140175801E-03	0.0	0.0	0.0	0.0
5	0.292376311E-03	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0
7	0.132432795E-03	-0.119796235E-03	0.0	0.0	0.0	0.0
8	0.0	-0.910276087E-04	0.0	0.0	0.0	0.0

FIGURE III-F.16 DISPLACEMENT OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

REACTIONS AND INVERSE CHECK FOR LOAD CONDITION 1

ROW	FX	FY	FZ	MX	MY	MZ
1	-0.225890011E 03	0.23636719E 02	0.0	0.0	0.0	0.0
2	-0.195312500E-02	-0.141049777E 03	0.0	0.0	0.0	0.0
3	-0.122070031E-02	0.18310547E-03	0.0	0.0	0.0	0.0
4	-0.122912410E 03	0.97656250E-03	0.0	0.0	0.0	0.0
5	0.396728852E-03	0.117410260E 03	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0
7	0.793457030E-03	-0.822953180E-03	0.0	0.0	0.0	0.0
8	-0.718859380E 03	-0.732421870E-03	0.0	0.0	0.0	0.0

FIGURE III-F.17 REACTION OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

STRESSES FOR THE QUADRILATERAL THIN SHELL ELEMENT

(STRESS POINT FIVE EQUALS ELEMENT STRESSES EVALUATED AT THE CENTROID)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	21	1 2 3 4 5 0 7 8

APPARENT ELEMENT STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR NORMAL(QX)	NORMAL(QY)
1	0.889579E 02	-0.152884E 02	-0.210226E-04	0.0	0.0	0.0	0.0	0.0
2	0.106171E 03	0.278698E 02	-0.222834E 02	0.0	0.0	0.0	0.0	0.0
3	0.305808E 02	0.517107E 01	-0.242977E 01	0.0	0.0	0.0	0.0	0.0
4	0.476818E 02	0.372644E 01	-0.269876E 01	0.0	0.0	0.0	0.0	0.0
5	0.635874E 02	-0.107391E 02	-0.173352E 01	0.0	0.0	0.0	0.0	0.0

ELEMENT APPLIED STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR NORMAL(QX)	NORMAL(QY)
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR NORMAL(QX)	NORMAL(QY)
1	0.889579E 02	-0.152884E 02	-0.210226E-04	0.0	0.0	0.0	0.0	0.0
2	0.106171E 03	0.278698E 02	-0.222834E 02	0.0	0.0	0.0	0.0	0.0
3	0.305808E 02	0.517107E 01	-0.242977E 01	0.0	0.0	0.0	0.0	0.0
4	0.476818E 02	0.372644E 01	-0.269876E 01	0.0	0.0	0.0	0.0	0.0
5	0.635874E 02	-0.107391E 02	-0.173352E 01	0.0	0.0	0.0	0.0	0.0

FIGURE III-F.18 STRESS OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

FORCES FOR THE QUADRILATERAL THIN SHELL ELEMENT

(THE FIRST FOUR POINTS ARE CORNER POINTS AND THE LAST FOUR POINTS ARE MID-POINTS)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	21	1 2 3 4 5 0 7 8

APPARENT ELEMENT FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS RZ
1	-0.22589011E 03	0.23636719E 02	0.0	0.0	0.0	0.0
2	0.66766797E 03	-0.14104977E 03	0.0	0.0	0.0	0.0
3	0.39999870E 03	0.18310547E-03	0.0	0.0	0.0	0.0
4	-0.12291241E 03	0.97656250E-03	0.0	0.0	0.0	0.0
5	0.39672852E-03	0.11741026E 03	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0
7	0.79345703E-03	-0.82295310E-03	0.0	0.0	0.0	0.0
8	-0.71085938E 03	-0.73242187E-03	0.0	0.0	0.0	0.0

ELEMENT APPLIED FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS RZ
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS RZ
1	-0.22589011E 03	0.23636719E 02	0.0	0.0	0.0	0.0
2	0.66766797E 03	-0.14104977E 03	0.0	0.0	0.0	0.0
3	0.39999870E 03	0.18310547E-03	0.0	0.0	0.0	0.0
4	-0.12291241E 03	0.97656250E-03	0.0	0.0	0.0	0.0
5	0.39672852E-03	0.11741026E 03	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0
7	0.79345703E-03	-0.82295310E-03	0.0	0.0	0.0	0.0
8	-0.71085938E 03	-0.73242187E-03	0.0	0.0	0.0	0.0

FIGURE III-F.19 ELEMENT FORCE OUTPUT, SQUARE PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

G. SQUARE PLATE - NORMAL PRESSURE LOADING - (Quadrilateral Thin Shell Idealization)

A simply supported isotropic square plate, under the action of normal pressure loading is shown in Figure III-G.1 along with its dimensions and pertinent material properties. This plate is idealized utilizing one quadrilateral thin shell element.

The preprinted input data forms associated with this example are shown in Figures III-G.2 through III-G.11.

In Figure III-G.5 (Gridpoint Coordinate Section) it can be seen that only the gridpoint coordinates for the four corner points of the element are entered. The coordinates associated with mid-point modes are calculated internally by the MAGIC System.

In Figure III-G.6 (Gridpoint Pressure Section) the MODAL entry is used for the input pressure values. This entry means that the normal pressures are acting at every grid point with a value of -1.0 psi. The sign of the pressure is minus since its direction is in the negative element Z_E direction.

In Figure III-G.7 (Boundary Condition Section) it is instructive to note the nature of the boundary conditions which apply to each grid point (see Figure III-G.1). Let us examine the Listed Input (Exceptions to the MODAL Card) first.

(1) Grid Point Number 1 (center of plate) has an unknown displacement in the w direction, all others are zero due to symmetry.

(2) Grid Point Number 2 has an unknown rotation, θ_y. The others are Zero due to the fact that the gridpoint 2 is a point of simple support.

(3) Grid Point Number 3 has all degrees of freedom fixed. This is due to the fact that this is the point where the simple supports meet restricting rotation in the θ_x and θ_y directions.

(4) Grid Point Numbers 5 and 8 are repeated and also have all degrees of freedom fixed. These are midside nodes and the only possible degrees of freedom allowed are u, v, and θ_n (θ normal). Since this is a pure bending problem, u and v are equal to zero. Since Grid Points 5 and 8 lie along symmetric boundaries θ_n equals zero.

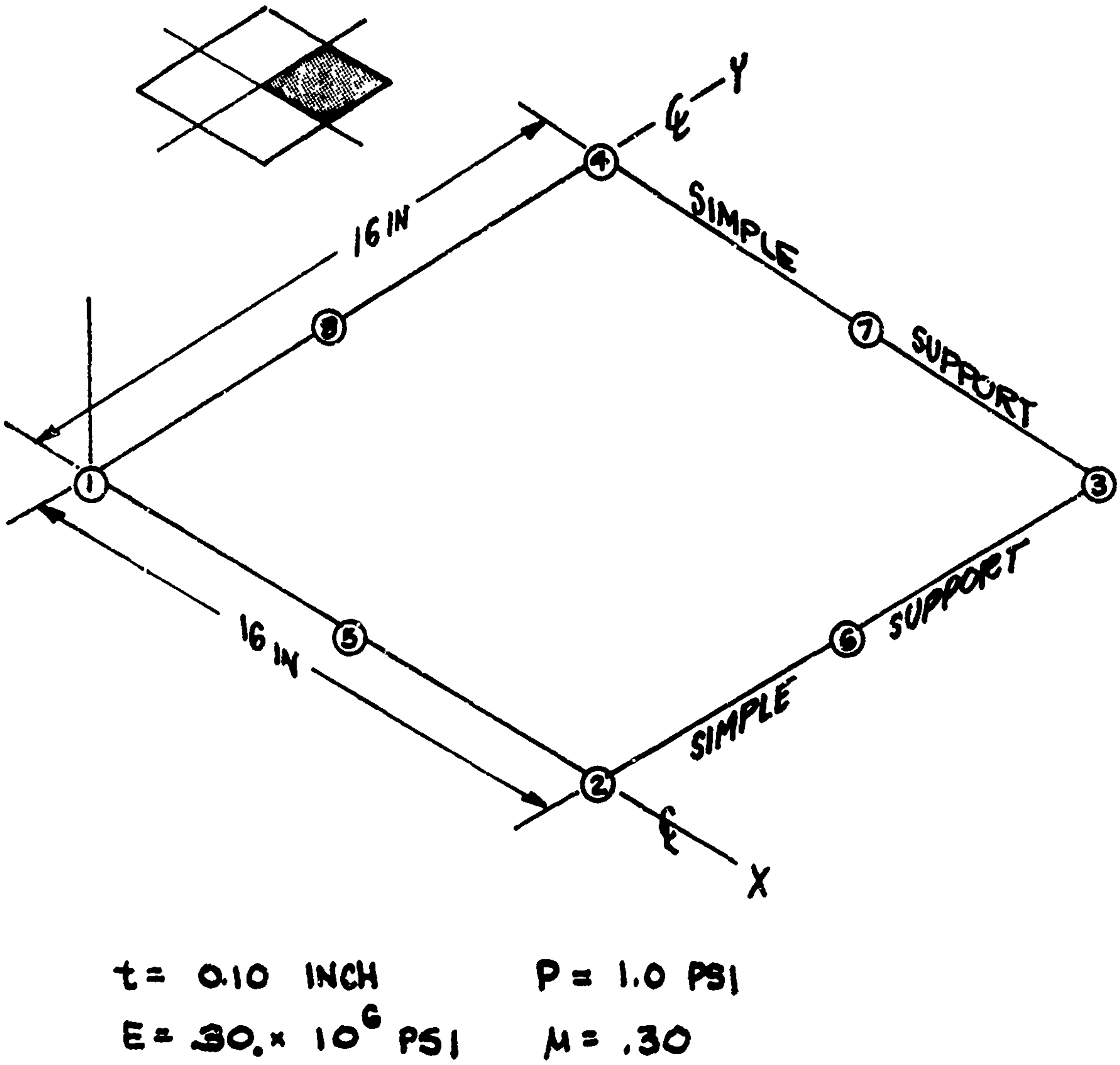


FIGURE III - G.1 - Idealized Simply Supported Plate with Normal Pressure Loading (Quadrilateral Thin Shell Idealization)

The MODAL card is now examined for the remaining grid points. Since Grid Point Numbers 1, 2, 3, 5, and 8 were called out under Listed Input, the MODAL entry pertains to Grid Point Numbers 4, 6, and 7.

(1) Grid Point Number 4 has an unknown rotation, θ_x. The others are zero since Grid Point 4 is a point of simple support.

(2) Grid Points 6 and 7 are mid-side nodes and the only possible degrees of freedom allowed are u, v, and θ_n (θ normal). Since this is a pure bending problem, u and v are equal to zero. However, there is an unknown slope θ_n, associated with these grid points. The Code (0, 1, 2) associated with these normal slope values is always entered in the θ_x location for consistency.

In Figure III-G.8 (External Loads Section) the following information is evident.

(1) One load condition is input

(2) The External Applied Load Scalar equals 1.0

(3) The MODAL option is employed and External Force and Moment values of 0.0 are entered in the appropriate locations. Since the Quadrilateral Thin Shell Element is formulated with six degrees of freedom per point, two external load cards per grid point are required.

The Element Applied Load Scalar was set equal to 1.0 because of the following:

Total Load = External Loads + EALS (Element Applied Loads)

Since the External Loads are equal to zero, and the EALS = 1.0

Total Load = Element Applied Load

These are the correct loads since for this case the Element Applied Loads are equal to the normal pressure loads.

In Figure III-G.9 (Element Control Data Section) the following information is of importance.

(1) The numbers '1' and '2' are entered in locations 11 and 12 of the node point portion of the Element Control Section. These two points define the direction of the (X) stress axis. With this definition, the stresses in the other directions retain their proper orientation with respect to this axis. It should be noted that the stress axis determination is element related and therefore if locations 11 and 12 are used for stress directions, then each following element (if they exist) must be considered separately and node points related to that particular element would be used in determining the stress direction.

In Figure III-G.10 (Element Input Section) only one item of information is entered in Location B as follows:

Location B - Flexural Thickness (t_f) = 0.10

BAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

REPORT (/)

1 2 3 4 5 6
TITLE (/)

7 8 9
3 (/) NUMBER OF TITLE CARDS

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

```
SIMPLY SUPPORTED QUADRILATERAL THIN PLATE SUBJECTED TO A        (/
UNIFORM NORMAL PRESSURE LOAD OF 1 PSI- ONE QUADRILATERAL        (/
THIN SHELL ELEMENT USED IN THE IDEALIZATION                     (/
                                                                (/)
                                                                (/)
                                                                (/)
                                                                (/)
                                                                (/)
                                                                (/)
```


FIGURE III-G.2 TITLE INFORMATION, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

M	A	T	E	R	
1	2	3	4	5	6

(/)

7	8	9
		1

No. of Requests (/)

MATERIAL TAPE INPUT

Request Number (7–9)	MATERIAL NUMBER (10–15)	Lock Code (16–17)	MATERIAL IDENTIFICATION (18–41)	Isotropic (42)	Orthotropic (43)	Plastic Isotropic (44)	Plastic Orthotropic (45)	Add Plastic (46)	Delete Material (47)	Print Tape (48)	Print Mat'l. Table (49)	Print Mat'l. Summary (50)	Number of Mat'l. Pts. (51–52)	Number of Plastic Pts. (53–54)	MASS DENSITY (55–64)	
1	12	TU	STEEL-E=30.0E6, MU=0.30	X							X		1		0.0005	(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE (13–22)	Direction	YOUNGS MODULI (23–32)	Direction	POISSONS RATIOS (33–42)	Direction	COEF. OF THERMAL EXPANSION (43–52)	Direction	RIGIDITY MODULI (53–62)	
0.0	E_x	30.0 E6	ν_{xy}	0.30	α_x	8.50 E-6	G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

FIGURE III-G.3 MATERIAL TAPE INPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

> ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

Item	Request	Entry	Columns
		S Y S T E M (/)	1 2 3 4 5 6
1.	Number of System Grid Points	8	1 2 3 4 5 6
2.	Number of Input Grid Points	4	7 8 9 10 11 12
3.	Number of Degrees of Freedom/Grid Point	6	13 14
4.	Number of Load Conditions	1	15 16
5.	Number of Initially Displaced Grid Points		17 18 19 20 21 22
6.	Number of Prescribed Displaced Grid Points		23 24 25 26 27 28
7.	Number of Grid Point Axes Transformation Systems		29 30
8.	Number of Elements	1	31 32 33 34 35 36
9.	Number of Requests and/or Revisions of Material Tape.	1	37 38
10.	Number of Input Boundary Condition Points	5	39 40 41 42 43 44
11.	T_o For Structure (With Decimal Point)	0.0 (/)	45 46 47 48 49 50 51 52

FIGURE III-G.4 SYSTEM CONTROL INFORMATION, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

BAC 1622

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1 2 3 4 5 6

C	O	O	R	C	

(/)

GRIDPOINT COORDINATE

	COORD. INPUT	Ø
SYSTEM	RECTANGULAR	R/Δ
	CYLINDRICAL	C
	SPHERICAL	S

Δ = BLANK

Ø	Grid Point Number (7–12)	X – R (13–22)	Y – θ (23–32)	Z – Z (33–42)	
	1	0.0	0.0	0.0	(/)
	2	16.0	0.0	0.0	(/)
	3	16.0	16.0	0.0	(/)
	4	0.0	16.0	0.0	(/)

FIGURE III-G.5 GRIDPOINT COORDINATES, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

GRID POINT PRESSURES

1 2 3 4 5 6	
PRESS	(/)

1 2 3 4 5 6	PRESSURES		
	P 1	P 2	P 3
	13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42
MODAL	-1.0		

Grid Point Number	Repeat	P 1	P 2	P 3	
7 8 9 10 11	12	13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42	
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
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					(/)
					(/)
					(/)
					(/)

FIGURE III-G.6 GRIDPOINT PRESSURES, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE - 0 - No Displacement Allowed
1 - Unknown Displacement
2 - Known Displacement

1	2	3	4	5	6	
B	O	U	N	D		(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	θx	θy	θz	1	2	3	
13	14	15	16	17	18	19	20	21	
0	0	0	1	0	0				(/)

LISTED INPUT

Grid Point Number 7	8	9	10	11	Repeat 12	13	14	15	16	17	18	19	20	21	
				1		0	0	1	0	0	0				(/)
				2		0	0	0	0	1	[illegible]				(/)
				3		0	0	0	0	0	0				(/)
				4											(/)
				5	X										(/)
				8	X										(/)
															(/)
															(/)
															(/)
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															(/)
															(/)

FIGURE III-G.7 BOUNDARY CONDITIONS, SIMPLY SUPPORTED PLATE
(QUADRILATERAL THIN SHELL IDEALIZATION)

BAC 1827

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

Transformation Code For Loads

LOADS	
LCOND	Condition Number: 1 Scale: 1.0

EXTERNAL LOADS

	FORCE VALUES			MOMENT VALUES			GENERALIZED VALUES		
	F_x	F_y	F_z	M_x	M_y	M_z	1	2	3
MODAL	0.0	0.0	0.0	0.0	0.0	0.0			
Grid Pt. Number									

FIGURE III-G.8 EXTERNAL LOADS, SIMPLY SUPPORTED PLATE
(QUADRILATERAL THIN SHELL IDEALIZATION)

BAC 1620

E	L	E	M		
1	2	3	4	5	6

(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER (7-10)	PLUG NO. (11-12)	MATERIAL NUMBER (13-18)	Interpolate Option (19)	MATERIAL TEMPERATURE (20-27)	Repeat Elem. Matrices (28)	Elem. Input (29)	PRINT: Print (30)	PRINT: Elem. Mat. (31)	PRINT: Full (32)	Number of Input Nodes (33-34)	Suppress Pressures (35)	NODE POINTS 1 (36-38)	2 (39-41)	3 (42-44)	4 (45-47)	5 (48-50)	6 (51-53)	7 (54-56)	8 (57-59)	9 (60-62)	10 (63-65)	11 (66-68)	12 (69-71)	
1	21	12				X			X	8		1	2	3	4	5	6	7	8			1	2	(/)
																								(/)
																								(/)
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FIGURE III-G.9 ELEMENT CONTROL DATA, SIMPLY SUPPORTED PLATE
(QUADRILATERAL THIN SHELL IDEALIZATION)

BAC 1629-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT INPUT

1 2 3 4 5 6	(/)
EXTERN	(/)

1 2 3 4 5 6	A (13–22)	B (23–32)	C (33–42)	D (43–52)	E (53–62)	F (63–72)
MODAL	0.0	0.10	0.0	0.0	0.0	

Element Number (7–11)	Repeat (12)	A (13–22)	B (23–32)	C (33–42)	D (43–52)	E (53–62)	F (63–72)	
								(/)
								(/)
								(/)
								(/)
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								(/)
								(/)
								(/)

FIGURE III-G.10 ELEMENT INPUT, SIMPLY SUPPORTED PLATE
(QUADRILATERAL THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM

INPUT DATA FORMAT

CHECK OR END CARD

C	H	E	C	K
1	2	3	4	5

(/)

E	N	D
1	2	3

(/)

FIGURE III-G.11 END CARD, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

The output supplied by the MAGIC System for the simply supported isotropic square plate subjected to a normal pressure load and idealized using one quadrilateral thin shell element is as follows:

Figures III-G.12 thru III-G.14 display the output from the Structural Systems Monitor. These figures record the input data pertinent to the problem being solved.

The Gridpoint Data Information is shown in Figure III-G.13. Note that pressures of -1.0 psi are applied at each gridpoint. The finite element information is also shown in Figure III-G.13. Under the section titled External Input, the second entry has a numerical value of 0.09999999. This value is equal to the flexural thickness of the plate being analyzed.

Figure III-G.14 displays the Transformed External Assembled Load Column. Note that these loads are all equal to zero since input pressures are element applied loads.

MAGIC System level output of final results is shown in Figures III-G.15 thru III-G.20.

Figure III-G.15 shows the assembled and reduced stiffness matrix. The stiffness matrix is read row-wise and only non-zero terms are displayed. The ordering of the stiffness matrix is consistent with that of the boundary conditions shown in Figure III-G.13. For this case the displacement vector is ordered as follows:

$$\{q\}^T = \lfloor w_1, \theta_{y2}, \theta_{x4}, \theta_{n6}, \theta_{n7} \rfloor$$

Where θ_{ni} = normal slope at node point i

Figure III-G.16 displays the Element Applied Loads (GPRINT OF MATRIX FTELA). Note that the components of load which arise from the uniform normal pressure are output against node point number. It is also to be noted that all membrane components of load(F_X and F_Y) are equal to zero. This arises since membrane and bending action are uncoupled and the only forces generated by the work equivalentnormal pressure loads are F_Z, M_X and M_Y.

The displacements for this application are presented in Figure III-G.17. Note that rows 6 and 7 correspond to mid-side grid points 6 and 7. The THETAX values of -0.11730331 correspond to the normal slopes at these mid-points. This is true since mid-side nodes have only U, V, and θ_n degrees of freedom. In addition, the displacements are referenced to the Global Axis unless otherwise indicated.

Figure III-G.18 displays the reactions for this application. These reactions are listed against grid point number and are referenced to the Global Coordinate System.

Stress resultants for the Quadrilateral Thin Shell Element are shown in Figure III-G.19. Eight stress resultants are evaluated at each corner point of the quadrilateral and also at the diagonal intersection, yielding a total of 40 stress resultants per element.

The stress resultants for the quadrilateral thin shell were explicitly defined in Section III-G (Square Plate-Parabolic Membrane Loading). Sketches were also provided to facilitate proper interpretation of the stress resultants.

The stress vector is in general referenced to the element coordinate system. For the quadrilateral or triangular thin shell elements however, the User has the option of specifying material or stress axes in order to effectively define stress output direction. This is accomplished by utilizing locations 9 and 10 or 11 and 12 of the node point portion of the Element Control Section. In this particular problem the numbers '1' and '2' were entered in locations 11 and 12 of the node point portion of the Element Control Section for Element Number 1. These two points define the X direction of the stress axis (positive X from node point 1 to node point 2). These axes of reference then become the reference stress axis.

Note that the stresses are evaluated at five stress points 1 thru 5. The first four correspond to the four corner points of the element (Node points 1 thru 4) while the fifth point corresponds to the element centroid.

Element forces for the quadrilateral thin shell element are presented in Figure III-G.20. These forces are defined with respect to the Global Coordinate System. The element forces are evaluated at eight points. The first four points (1 thru 4) and the last four points are mid-points (node points 5 thru 8). Note that the mid-side nodes have allowable degrees-of-freedom equal to U, V and normal slope (θ_n).

```
SIMPLY SUPPORTED ISOTROPIC SQUARE PLATE SUBJECTED TO A
UNIFORM NORMAL PRESSURE LOAD OF 1 PSI- ONE QUADRILATERAL
THIN SHELL ELEMENT USED IN THE IDEALIZATION
                         REVISIONS OF MATERIAL TAPE

                        ASTERISK (*) PRECEEDING MATERIAL
                        IDENTIFICATION INDICATES THAT INPUT
                        ERROR RETURNS WILL NOT RESULT IN
                            TERMINATION OF EXECUTION

*************************************************************************************

  REVISION
    MATERIAL NUMBER     12
    MATERIAL IDENTIFICATION     STEEL                     INPUT CODE   I
      NUMBER OF MATERIAL PROPERTY POINTS. . . . 1
      NUMBER OF PLASTIC PROPERTY POINTS . . . . -0
      MASS DENSITY. . . . . . . . . . . . . . .-0.

    MATERIAL PROPERTIES

                     YOUNG'S MODULI                               POISSON'S RATIOS

                       DIRECTIONS                                    DIRECTIONS
 TEMPERATURE
                XX             YY             ZZ               XY             YZ             ZX
    0.      0.300000E 08   0.300000E 08   0.300000E 08     0.300000E 00   0.300000E 00   0.300000E 00
                 THERMAL EXPANSION COEFFICIENTS                    RIGIDITY MODULI

                       DIRECTIONS                                    DIRECTIONS
 TEMPERATURE
                XX             YY             ZZ               XY             YZ             ZX
    0.      -0.            -0.            -0.              0.115385E 08   0.115385E 08   0.115385E 08

*************************************************************************************
```

FIGURE III-G.12 TITLE AND MATERIAL DATA OUTPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

8 REF. POINTS

NO. DIRECTIONS = 3 NO. DEGREES OF FREEDOM = 2

GRIDPOINT DATA
(IN RECTANGULAR COORDINATES)

POINT	X	Y	Z	TEMPERATURES	PRESSURES
1	0.0	0.0	0.0	0.0	-0.10000000E 01
				0.0	0.0
				0.0	0.0
2	0.16000000E 02	0.0	0.0	0.0	-0.10000000E 01
				0.0	0.0
				0.0	0.0
3	0.16000000E 02	0.16000000E 02	0.0	0.0	-0.10000000E 01
				0.0	0.0
				0.0	0.0
4	0.0	0.16000000E 02	0.0	0.0	-0.10000000E 01
				0.0	0.0
				0.0	0.0

BOUNDARY CONDITION INFORMATION

NODES	DEGREES OF FREEDOM						NO. OF ONES	NO. OF TWOS
1	0	0	1	0	0	0	1	0
2	0	0	0	0	1	0	2	0
3	0	0	0	0	0	0	2	0
4	0	0	0	1	0	0	3	0
5	0	0	0	0	0	0	3	0
6	0	0	0	1	0	0	4	0
7	0	0	0	1	0	0	5	0
8	0	0	0	0	0	0	5	0

FIGURE III-G.13 GRIDPOINT DATA, BOUNDARY CONDITION AND FINITE ELEMENT DESCRIPTION OUTPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION.)

```
                                   TOTAL NO. ELEMENTS =      1

ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NO.    --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES ----
  1   21      12    0   0.0        2     8     1  2  3  4  5  6  7  8        0  0  1  2

MATERIAL NUMBER. . . . . . . . .    12
     MATERIAL IDENTIFICATION. . . .   STEEL
     ANALYSIS CAPABILITY. . . . . .  ISOTROPIC
     INPUT PRINT CODE . . . . . . .  1
     ELEMENT PRINT CODE . . . . . . -1



INTERPOLATED MATERIAL PROPERTIES
     TEMPERATURE -         0.0
     YOUNG'S MODULI        0.30000000E 08      0.30000000E 08      0.30000000E 08
     POISSON'S RATIO       0.29999995E 00      0.29999995E 00      0.29999995E 00
     TH. EXP. COEF.        0.0                 0.0                 0.0
     RIGIDITY MODULI       0.11538468E 08      0.11538468E 08      0.11538468E 08

INTERPOLATED PLASTIC PROPERTIES
     NONE

PRE-STRAIN INPUT
     NONE

PRE-STRESS INPUT
     NONE

EXTERNAL INPUT
          0.0                0.99999964E-01    0.0              0.0              0.0
```

FIGURE III-G.13 GRIDPOINT DATA, BOUNDARY CONDITION AND FINITE ELEMENT DESCRIPTION OUTPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION) (CONTINUED)

EXTERNAL LOAD CONDITIONS 1

LOAD NO. 1

NUMBER OF LOADED NODES 8 ELEMENT LOAD SCALAR = 0.10000000E 01

1	0.	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.	0.
3	0.	0.	0.	0.	0.	0.
4	0.	0.	0.	0.	0.	0.
5	0.	0.	0.	0.	0.	0.
6	0.	0.	0.	0.	0.	0.
7	0.	0.	0.	0.	0.	0.
8	0.	0.	0.	0.	0.	0.

TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN

48 X 1

0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.

T-ZERO FOR STRUCTURE = 0.

FIGURE III-G.14 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

MATRIX STIFF

PAGE 1

CUTOFF = 0.

SIZE 5 BY 5

	FORCE		FORCE		FORCE		FORCE		FORCE	
DISP. 1	1	0.128777E 03	2	-0.171703E 03	3	0.171703E 03	4	-0.343407E 03	5	-0.343407E 03
DISP. 2	1	-0.171703E 03	2	0.618132E 04	3	-0.686813E 03	4	-0.549450E 04	5	-0.915751E 03
DISP. 3	1	0.171703E 03	2	-0.686813E 03	3	0.618132E 04	4	0.915751E 03	5	0.549450E 04
DISP. 4	1	-0.343407E 03	2	-0.549450E 04	3	0.915751E 03	4	0.183150E 05	5	-0.366300E 04
DISP. 5	1	-0.343407E 03	2	-0.915751E 03	3	0.549450E 04	4	-0.366300E 04	5	0.183150E 05

FIGURE III-3.15 REDUCED STIFFNESS MATRIX
SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

GPRINT OF MATRIX FTELA (SET 1)

ROW	FX	FY	FZ	MX	MY	MZ
1	0.0	0.0	-0.63999939E 02	-0.10239998E 03	0.10239963E 03	0.0
2	0.0	0.0	-0.63999954E 02	-0.10239972E 03	-0.10239963E 03	0.0
3	0.0	0.0	-0.639[illegible]983E 02	0.10240068E 03	-0.10239993E 03	0.0
4	0.0	0.0	-0.63999924E 02	0.10239987E 03	0.10240016E 03	0.0
5	0.0	0.0	0.0	-0.13653355E 03	0.0	0.0
6	0.0	0.0	0.0	-0.13653343E 03	0.0	0.0
7	0.0	0.0	0.0	-0.13653270E 03	0.0	0.0
8	0.0	0.0	0.0	0.13653291E 03	0.0	0.0

FIGURE III-G.16 ELEMENT APPLIED LOAD OUTPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

DISPLACEMENT MATRIX FOR LOAD CONDITION 1

48 X 1

ROW	U	V	W	THETAX	THETAY	THETAZ
1	0.0	0.0	-0.15581980E 01	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	-0.163347713E 00	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.163347724E 00	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	-0.117300331E 00	0.0	0.0
7	0.0	0.0	0.0	-0.117300313E 00	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE III-G.17 DISPLACEMENT OUTPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

REACTIONS AND INVERSE CHECK FOR LOAD CONDITION 1

ROW	FX	FY	FZ	MX	MY	MZ
1	0.0	0.0	0.91552734E-04	-0.13628331E 03	0.13628273E 03	0.0
2	0.0	0.0	0.99820847E 02	0.25253183E 03	0.33569336E-03	0.0
3	0.0	0.0	0.56357849E 02	-0.19024590E 03	0.19024222E 03	0.0
4	0.0	0.0	0.99821198E 02	-0.11901855E-02	-0.25253444E 03	0.0
5	0.0	0.0	0.0	-0.37686279E 03	0.0	0.0
6	0.0	0.0	0.0	0.22888184E-03	0.0	0.0
7	0.0	0.0	0.0	-0.90354004E-03	0.0	0.0
8	0.0	0.0	0.0	0.37686401E 03	0.0	0.0

FIGURE III-G.18 REACTION OUTPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

STRESSES, FOR THE QUADRILATERAL THIN SHELL ELEMENT

(STRESS POINT FIVE EQUALS ELEMENT STRESSES EVALUATED AT THE CENTROID)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS							
			1	2	3	4	5	6	7	8
1	1	21								

APPARENT ELEMENT STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR NORMAL(QX)	NORMAL(QY)
1	0.0	0.0	0.0	-0.575064E 02	-0.575064E 02	-0.879423E-05	-0.286174E 01	0.359379E 01
2	0.0	0.0	0.0	-0.828250E 01	-0.248494E 01	0.290341E 01	-0.432586E 01	0.359377E 01
3	0.0	0.0	0.0	0.106812E-03	0.320435E-03	0.367625E 02	-0.432587E 01	-0.359379E 01
4	0.0	0.0	0.0	-0.713394E 01	-0.129315E 02	0.929359E-04	-0.286176E 01	-0.359377E 01
5	0.0	0.0	0.0	-0.341365E 02	-0.341365E 02	0.154824E 02	-0.359382E 01	0.476857E-05

ELEMENT APPLIED STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR NORMAL(QX)	NORMAL(QY)
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR NORMAL(QX)	NORMAL(QY)
1	0.0	0.0	0.0	-0.575064E 02	-0.575064E 02	-0.879423E-05	-0.286174E 01	0.359379E 01
2	0.0	0.0	0.0	-0.828250E 01	-0.248494E 01	0.290341E 01	-0.432586E 01	0.359377E 01
3	0.0	0.0	0.0	0.106812E-03	0.320435E-03	0.367625E 02	-0.432587E 01	-0.359379E 01
4	0.0	0.0	0.0	-0.713394E 01	-0.129315E 02	0.929359E-04	-0.286176E 01	-0.359377E 01
5	0.0	0.0	0.0	-0.341365E 02	-0.341365E 02	0.154824E 02	-0.359382E 01	0.476857E-05

FIGURE III-G.19 STRESS OUTPUT, SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

FORCES FOR THE QUADRILATERAL THIN SHELL ELEMENT

(THE FIRST FOUR POINTS ARE CORNER POINTS AND THE LAST FOUR POINTS ARE MID-POINTS)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	21	1 2 3 4 5 6 7 8

APPARENT ELEMENT FORCES

POINT	FORCES FX	FY	FZ	MOMENTS MX	MY	MZ
1	0.0	0.0	-0.63999847E 02	-0.23868329E 03	0.23868236E 03	0.0
2	0.0	0.0	0.35820892E 02	0.15013211E 03	-0.10239929E 03	0.0
3	0.0	0.0	-0.76421356E 01	-0.87845215E 02	0.87842285E 02	0.0
4	0.0	0.0	0.35821274E 02	0.10239866E 03	-0.15013428E 03	0.0
5	0.0	0.0	0.0	-0.51339648E 03	0.0	0.0
6	0.0	0.0	0.0	-0.13653320E 03	0.0	0.0
7	0.0	0.0	0.0	-0.13653320E 03	0.0	0.0
8	0.0	0.0	0.0	0.51339697E 03	0.0	0.0

ELEMENT APPLIED FORCES

POINT	FORCES FX	FY	FZ	MOMENTS MX	MY	MZ
1	0.0	0.0	-0.63999939E 02	-0.10239998E 03	0.10239963E 03	0.0
2	0.0	0.0	-0.63999954E 02	-0.10239972E 03	-0.10239963E 03	0.0
3	0.0	0.0	-0.63999985E 02	0.10240068E 03	-0.10239993E 03	0.0
4	0.0	0.0	-0.63999924E 02	0.10239987E 03	0.10240016E 03	0.0
5	0.0	0.0	0.0	-0.13653355E 03	0.0	0.0
6	0.0	0.0	0.0	-0.13653343E 03	0.0	0.0
7	0.0	0.0	0.0	-0.13653270E 03	0.0	0.0
8	0.0	0.0	0.0	0.13653291E 03	0.0	0.0

NET ELEMENT FORCES

POINT	FORCES FX	FY	FZ	MOMENTS MX	MY	MZ
1	0.0	0.0	0.91552734E-04	-0.13628331E 03	0.13628273E 03	0.0
2	0.0	0.0	0.99820847E 02	0.25253183E 03	0.33569336E-03	0.0
3	0.0	0.0	0.56357849E 02	-0.19024590E 03	0.19024222E 03	0.0
4	0.0	0.0	0.99821298E 02	-0.11901855E-02	-0.25253444E 03	0.0
5	0.0	0.0	0.0	-0.37686279E 03	0.0	0.0
6	0.0	0.0	0.0	0.22888184E-03	0.0	0.0
7	0.0	0.0	0.0	-0.50354004E-03	0.0	0.0
8	0.0	0.0	0.0	0.37686401E 03	0.0	0.0

FIGURE III-G.20 ELEMENT FORCE OUTPUT. SIMPLY SUPPORTED PLATE (QUADRILATERAL THIN SHELL IDEALIZATION)

H. SQUARE PLATE - PARABOLIC MEMBRANE LOADING (Triangular Thin Shell Idealization)

An isotropic, square plate under the action of a parabolic membrane loading is shown in Figure III-H.1, along with its dimensions and pertinent material properties. The plate is idealized utilizing two triangular thin shell elements.

The preprinted input data forms associated with this example are shown in Figures III-H.2 through III-H.10.

In Figure III-H.5 (Gridpoint Coordinate Section) it can be seen that only the grid point coordinates for the three corner points of each element are entered. The coordinates associated with mid-point nodes are calculated internally by the MAGIC System.

In Figure III-H.6 (Boundary Condition Section) it is instructive to note the nature of the boundary conditions which apply to each grid point (See Figure III-H.1). Remember that in a pure membrane problem, u and v are the only degrees of freedom which are of interest.

Let us examine the Listed Input (Exceptions to the MODAL Card) first.

(1) Grid Point Number 1 (Center of Plate) has all degrees of freedom fixed. This is true because this grid point is at the center of the plate and the plate is loaded by a self-equilibrating parabolic membrane load.

(2) Grid Point Numbers 2 and 5 only have an unknown displacement in the u direction. This is true because these grid points lie along a symmetric boundary defined by the X axis.

(3) Grid Point Numbers 4 and 8 only have an unknown displacement in the v direction. This is true because these grid points lie along a symmetric boundary defined by the Y axis.

(4) Grid Point Number 6 is suppressed, therefore, all associated degrees of freedom are fixed.

The MODAL card is now examined for the remaining grid points. Since Grid Point Numbers 1, 2, 4, 5, and 8 were called out under Listed Input, the MODAL entry pertains to Grid Point Numbers 3, 7, and 9.

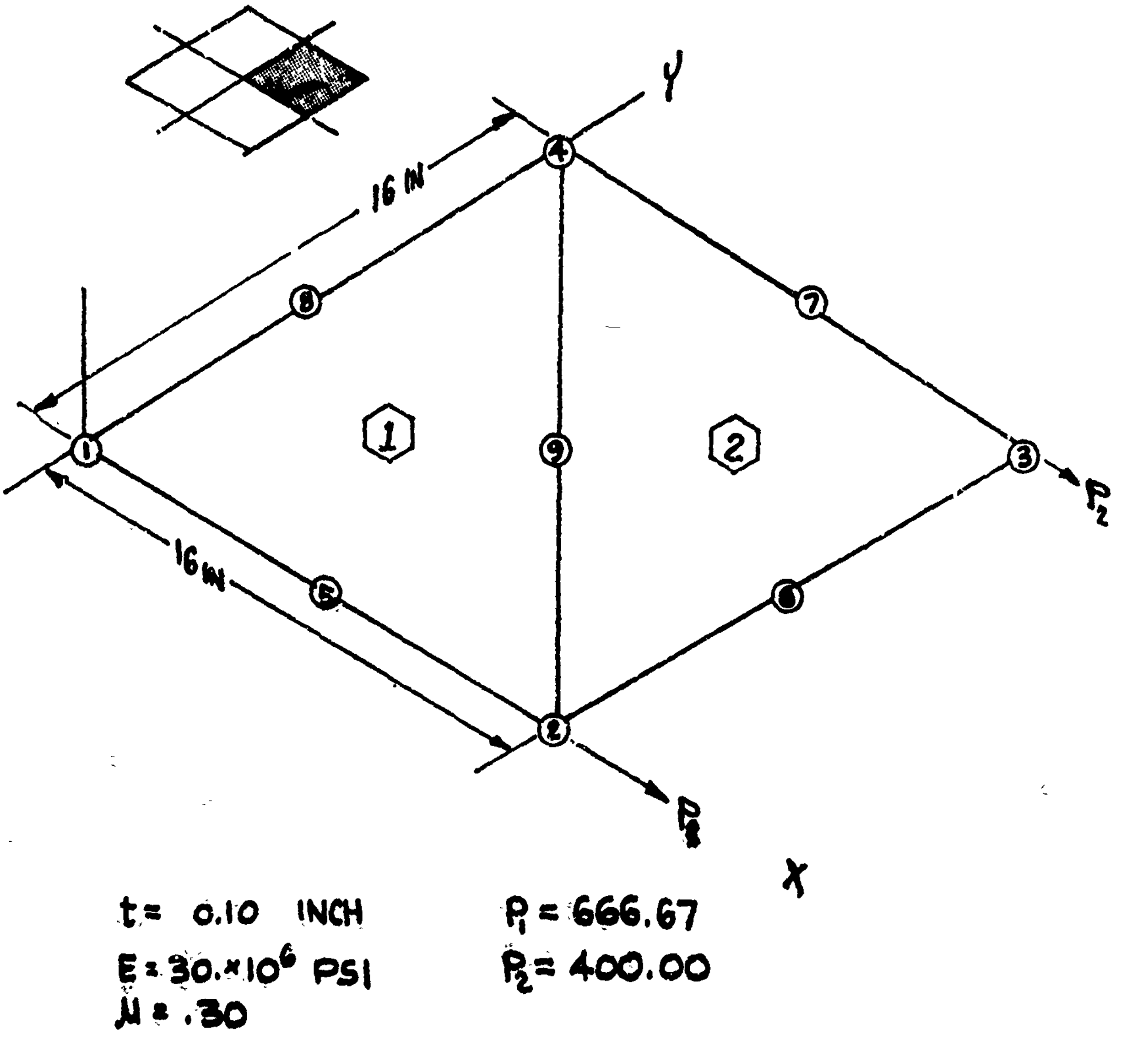


FIGURE III.- H.1 - Idealized Square Plate, Parabolic Membrane Loading (Triangular Thin Shell Idealization)

Grid Point Numbers 3, 7, and 9 have unknown displacements both in the u and v directions.

In Figure III-H.7 (External Loads Section) Grid Points 2 and 3 have applied external loading. Note that there are two external load cards per grid point.

In Figure III-H.8 (Element Control Data Section) the following information is of importance.

(1) For element number 2, mid-point node number 6 is suppressed. This element is therefore numbered 2, 3, 4, 0, 7, 9. These entries are made in the first six locations of the node point section as shown in Figure III-H.8.

(2) For element numbers 1 and 2, the numbers '1' and '2' are entered in locations 9 and 10 of the node point portion of the Element Control Section. These two points define the X direction for the material properties axes. This allows the User to effectively define stress output direction. The same two points, used for Element Number 1, can also be used for Element Number 2 as shown in the figure.

In Figure III-H.9 (Element Input Section) only one item of information is entered in Location A of the MODAL section.

Location A - Membrane Thickness (t_m) = 0.10

This MODAL entry signifies that this thickness applies to all elements used in this analysis.

BAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

REPORT (/)

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

TITLE (/)

6 (/) NUMBER OF TITLE CARDS

SIMPLY SUPPORTED QUADRILATERAL THIN PLATE SUBJECTED TO A SELF- (/)
EQUILIBRATING PARABOLIC MEMBRANE LOADINGS, TWO TRIANGULAR THIN (/)
SHELL ELEMENTS USED IN THE IDEALIZATION-MID-POINT NODE ON THE (/)
LOADED EDGE IS SUPPRESSED (/)
REFERENCE- TIMOSHENKO,S. AND GOODIER,J.N.-THEORY OF ELASTICITY (/)
SECOND EDITION, MC GRAW HILL, NEW YORK, 1951. (/)
(/)
(/)
(/)

FIGURE III-H.2 TITLE INFORMATION, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

BAC 1616-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MATER (/)
1 2 3 4 5 6

1 (/)
7 8 9
No. of Requests

MATERIAL TAPE INPUT

Request Number (7–9)	MATERIAL NUMBER (10–15)	Lock Code (16–17)	MATERIAL IDENTIFICATION (18–41)	Isotropic (42)	Orthotropic (43)	Plastic Isotropic (44)	Plastic Orthotropic (45)	Add Plastic (46)	Delete Material (47)	Print Tape (48)	Print Mat'l. Table (49)	Print Mat'l. Summary (50)	Number of Mat'l. Pts. (51–52)	Number of Plastic Pts. (53–54)	MASS DENSITY (55–64)	
1	12	TU	STEEL-E=30.0E6,MU=0.30	X							X		1		0.0005	(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE (13–22)	Direction	YOUNGS MODULI (23–32)	Direction	POISSONS RATIOS (33–42)	Direction	COEF. OF THERMAL EXPANSION (43–52)	Direction	RIGIDITY MODULI (53–62)	
0.0	E_x	30.0 E6	ν_{xy}	0.30	α_x	8.50 E-6	G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

FIGURE III-H.3 MATERIAL TAPE INPUT, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

		S Y S T E M	1 2 3 4 5 6 (/)
1.	Number of System Grid Points	9	1 2 3 4 5 6
2.	Number of Input Grid Points	4	7 8 9 10 11 12
3.	Number of Degrees of Freedom/Grid Point	6	13 14
4.	Number of Load Conditions	1	15 16
5.	Number of Initially Displaced Grid Points		17 18 19 20 21 22
6.	Number of Prescribed Displaced Grid Points		23 24 25 26 27 28
7.	Number of Grid Point Axes Transformation Systems		29 30
8.	Number of Elements	2	31 32 33 34 35 36
9.	Number of Requests and/or Revisions of Material Tape.	1	37 38
10.	Number of Input Boundary Condition Points	6	39 40 41 42 43 44
11.	T_o For Structure (With Decimal Point)	0.0	45 46 47 48 49 50 51 52 (/)

FIGURE III-H.4 SYSTEM CONTROL INFORMATION, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1 2 3 4 5 6

| C | O | O | R | D | |

(/)

GRIDPOINT COORDINATE

COORD. INPUT	₡
SYSTEM: RECTANGULAR	R/Δ
SYSTEM: CYLINDRICAL	C
SYSTEM: SPHERICAL	S

Δ = BLANK

₡ (5–6)	Grid Point Number (7–12)	DIRECTIONS X – R (13–22)	DIRECTIONS Y – θ (23–32)	DIRECTIONS Z – Z (33–42)	
	1	0.0	0.0	0.0	(/)
	2	16.0	0.0	0.0	(/)
	3	16.0	16.0	0.0	(/)
	4	0.0	16.0	0.0	(/)

FIGURE III-H.5 GRIDPOINT COORDINATES, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE - 0 - No Displacement Allowed
1 - Unknown Displacement
2 - Known Displacement

1	2	3	4	5	6	
B	O	U	N	D		(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	Θx	Θy	Θz	1	2	3	
13	14	15	16	17	18	19	20	21	
1	1	0	0	0	0				(/)

LISTED INPUT

Grid Point Number 7	8	9	10	11	Repeat 12	13	14	15	16	17	18	19	20	21	
				1		0	0	0	0	0	0				(/)
				7		1	0	0	0	0	0				(/)
				5	X										(/)
				4		0	1	0	0	0	0				(/)
				8	X										(/)
				6		0	0	0	0	0	0				(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)

FIGURE III-H.6 BOUNDARY CONDITIONS, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

MAC 1027

Transformation Code For Loads

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

LCOMB — Condition Number: 1 — Scale: 0.0

MODAL

EXTERNAL LOADS

	FORCE VALUES			MOMENT VALUES			GENERALIZED VALUES		
Grid Pt. Number	F_x	F_y	F_z	M_x	M_y	M_z	1	2	3
2	666.67	0.0	0.0	0.0	0.0	0.0			
3	[illegible].00	0.0	0.0	0.0	0.0	0.0			

FIGURE III-H.7 EXTERNAL LOADS, SQUARE PLATE
(TRIANGULAR THIN SHELL IDEALIZATION)

BAC 1020

E	L	E	M		
1	2	3	4	5	6

(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

Element Number (7-10)	Plug No. (11-12)	Material Number (13-18)	Interpolate Option (19)	Material Temperature (20-27)	Repeat Elem. Matrices (28)	Elem. Input (29)	Print: Print (30)	Print: Elem. Mat (31)	Print: Full (32)	Number of Input Nodes (33-34)	Suppress Pressures (35)	Node Points 1	2	3	4	5	6	7	8	9	10	11	12	
1	20	12				X			X	6		1	2	4	5	9	8			1	2			(/)
2	20	12				X				6		2	3	4	0	7	9			1	2			(/)

FIGURE III-H.8 ELEMENT CONTROL DATA, SQUARE PLATE
(TRIANGULAR THIN SHELL IDEALIZATION)

BAC 1629-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT INPUT

E	X	T	E	R	N	(/)
1	2	3	4	5	6	

1 2 3 4 5 6	A (13–22)	B (23–32)	C (33–42)	D (43–52)	E (53–62)	F (63–72)
MODAL	0.10	0.0	0.0	0.0	0.0	

Element Number (7–11)	Repeat (12)	13–22	23–32	33–42	43–52	53–62	63–72	
								(/
								(/
								(/
								(/
								(/
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)

FIGURE III-H.9 ELEMENT INPUT, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM

INPUT DATA FORMAT

CHECK OR END CARD

C	H	E	C	K	(/)
1	2	3	4	5	

E	N	D	(/)
1	2	3	

FIGURE III-H.10 END CARD, SQUARE PLATE
(TRIANGULAR THIN SHELL IDEALIZATION)

The output supplied by the MAGIC System for the thin square plate subjected to parabolic loading and idealized with two triangular thin shell elements is as follows:

Figures III-H.11 thru III-H.13 display the output from the Structural Systems Monitor. These figures record the input data pertinent to the problem beirg solved.

In Figure III-H.12, the finite element information is shown. Under the section titled External Input, the first. entry printed has a numberical value of 0.0999999. This value is equal to the membrane thickness of the plate being analyzed.

Figure III-H.13 displays the External Load Column for this problem. The 54 x 1 vector shown in the figure is the total unreduced transformed external load column which is read row-wise. The ordering is consistent with that of the boundary condition information shown in Figure III-H.12. An external load of 667.67 is applied at node point 2 and also at a load of 400.0 is applied at node point 3 both in the positive Global X direction.

MAGIC System level output of final results is shown in Figures III-H.14 thru III-H.21. Figure III-H.14 shows the reduced stiffness matrix for this problem. Only non-zero terms in the stiffness matrix are displayed. The stiffness matrix is presented row-wise and its ordering is consistent with that of the boundary conditions shown in Figure III-H.12. For this case, the ordering of the displacement vector is as follows:

$$\{q\}^T = \lfloor u_2, u_3, v_3, v_4, u_5, u_7, v_8, u_9, v_9 \rfloor$$

Figure III-H.15 displays the externally applied loads for this application (GPRINT OF MATRIX LOADS). These loads (F_X, F_Y, F_Z, M_X, M_Y, M_Z) are referenced to the Global Axis and are output against node point number. From the figure, it is seen that node points 2 and 3 are loaded by Forces, F_X, equal to 666.67 and 400.0 respectively. It is also to be noted that these forces are acting in the positive Global X direction.

Displacements are presented in Figure III-H.16. Displacements are output against node point number and are referenced to the Global Axis unless otherwise indicated.

Reactions are presented in Figure III-H.17. There are only two components of Reaction at any grid point (F_X and F_Y) since only membrane loading is involved and there is no coupling between membrane and bending action.

Stress resultants for the Triangular Thin Shell Element are presented in Figures III-H.18 and III-H.19. Eight stress resultants are evaluated at each corner point of the triangle and also at its centroid yielding a total of thirty-two stress resultants per element.

The stress resultants for the triangular thin shell element are defined as follows:

$$N_x = \int_z \sigma_x \, dz \qquad ; \text{ units } \frac{\text{force}}{\text{length}}$$

$$N_y = \int_z \sigma_y \, dz \qquad ; \text{ units } \frac{\text{force}}{\text{length}}$$

$$N_{xy} = \int_z \tau_{xy} \, dz \qquad ; \text{ units } \frac{\text{force x length}}{\text{length}}$$

$$M_x = \int_z z \, \sigma_x \, dz \qquad ; \text{ units } \frac{\text{force x length}}{\text{length}}$$

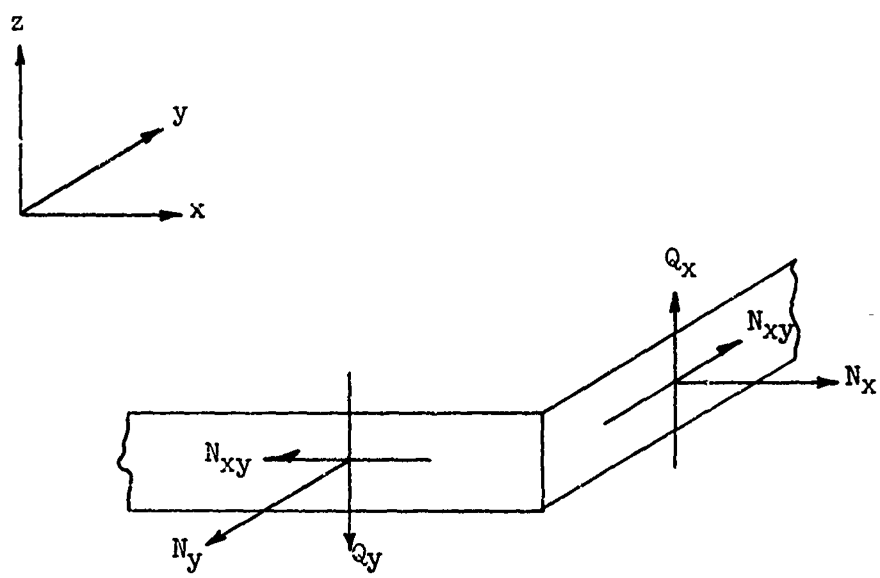
$$M_y = \int_z z \, \sigma_y \, dz \qquad ; \text{ units } \frac{\text{force x length}}{\text{length}}$$

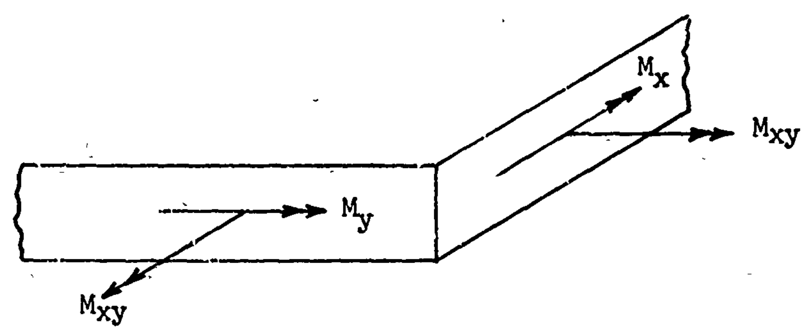
$$M_{xy} = \int_z z \, \tau_{xy} \, dz \qquad ; \text{ units } \frac{\text{force x length}}{\text{length}}$$

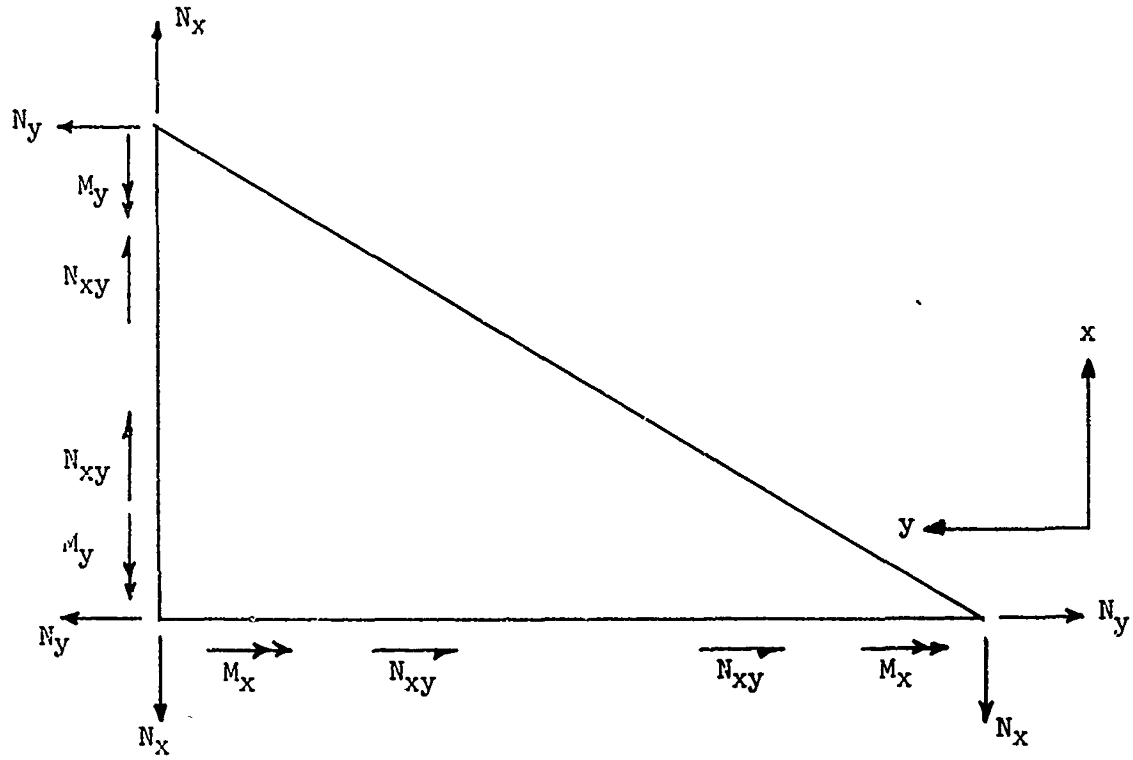
$$Q_x = \int_z z \frac{\partial \sigma_x}{\partial x} \, dz + \int_z z \frac{\partial \tau_{xy}}{\partial y} \, dz \qquad ; \text{ units } \frac{\text{force}}{\text{length}}$$

$$Q_y = \int_z z \left(\frac{\partial \sigma_y}{\partial y}\right) dz + \int_z z \left(\frac{\partial \tau_{xy}}{\partial x}\right) dz \qquad ; \text{ units } \frac{\text{force}}{\text{length}}$$

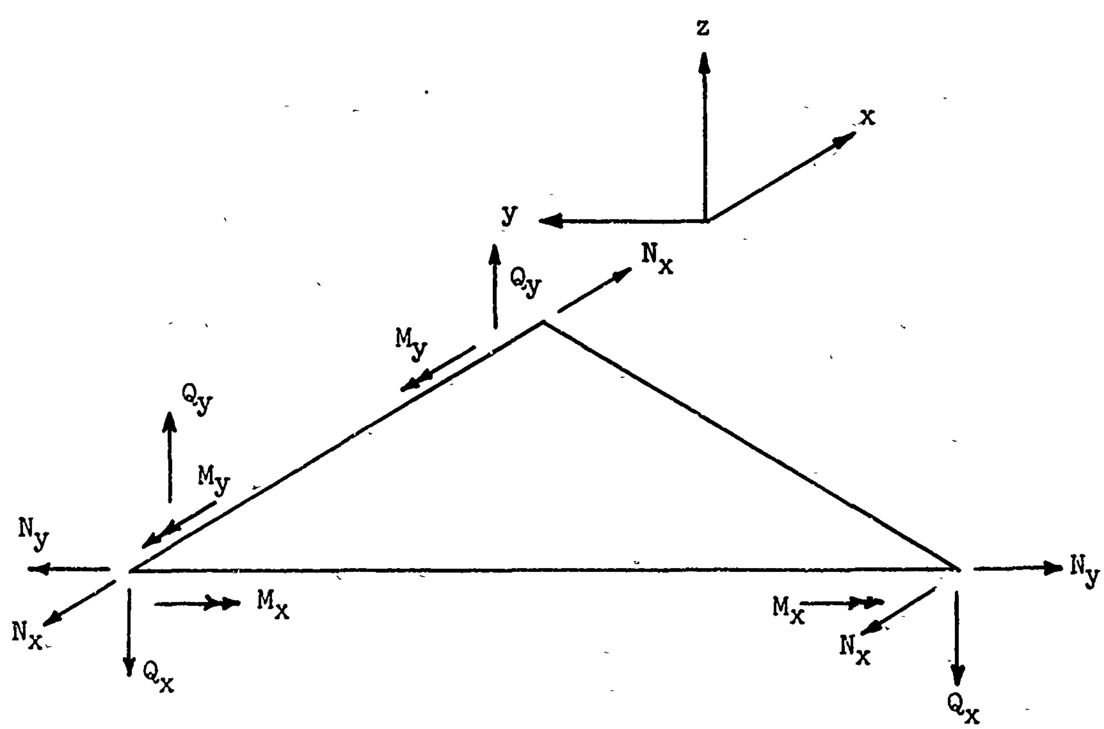
The following sketches show the proper manner in which to interpret the stress resultants.







N x
N y
M y
N xy
N xy
M y
N y
N x
M x
N xy
N xy
M x
N x
N y
x
y



z
x
y
N x
Q y
M y
Q y
M y
N y
N x
Q x
M x
M x
N x
Q x
N y

Figure III-H.18 presents the stress resultants for Element Number 1. Stress points 1, 2, 3, and 4 correspond to the following:

Stress point 1 equals the element stresses evaluated at the centroid. Stress points 2, 3, and 4 correspond to element corner points 1, 2, and 4 respectively.

Figure III-H.19 presents the stress resultants for Element Number 2. Stress points 1, 2, 3, and 4 correspond to the following:

Stress point 1 equals the element stresses evaluated at the centroid. Stress points 2, 3, and 4 correspond to element corner points 2, 3, and 4 respectively.

The stress vector is in general referenced to the element coordinate system. For the quadrilateral or triangular thin shell elements, however, the User has the option of specifying material or stress axes in order to effectively define stress output direction. This is accomplished by utilizing locations 9 and 10 or 11 and 12 of the node point portion of the Element Control Section. In this particular problem the numbers '1' and '2' were entered in locations 9 and 10 of the node point portion of the Element Control Section. These two points define the X direction of the material properties axes (Positive X from node point 1 to node point 2). This axis of reference then becomes the reference axis for the stress output.

There is one exception to the usual rules of presenting the stress output for the triangular thin shell element.

> For each triangular element, the centroidal values of the stress resultants for that element are the first to be printed. In the general case the node point stresses are printed and then the centroidal stresses.

Figures III-H.20 and III-H.21 present the element forces for the two triangular thin shell elements used in this application. The element is defined by six node points (3 corner points and 3 mid-side node points). Since there are six forces per node point (F_X, F_Y, F_Z, M_X, M_Y, M_Z) a total of 36 forces per element are defined. In Figure III-H.20, Force Points 1 thru 3 correspond to element corner points 1, 2, and 4. Force points 4 thru 6 correspond to element mid-points 5, 9 and 8. The forces for Element No. 2, shown in Figure III-H.21 are interpreted in an analogous manner to those for Element No. 1. It is to be noted that the element forces are referenced to the Global Axis unless otherwise indicated.

```
THIN SQUARE ISCTRCFIC PLATE SUBJECTED TO A SELF
EQUILIBRATING PARABOLIC MEMBRANE LOADING-TWO TRIANGULAR
THIN SHELL ELEMENTS USED IN THE IDEALIZATION,MID-POINT NODE ON
THE LOADED EDGE IS SUPPRESSED IN THIS ANALYSIS
REFERENCE-TIMOSHENCO,S.AND GOODIER,J.N.,THEORY OF ELASTICITY,
SECOND EDITION,MCGRAW HILL NEW YORK 1951.

                       REVISIONS OF MATERIAL TAPE

                     ASTERISK (*) PRECEEDING MATERIAL
                     IDENTIFICATION INDICATES THAT INPUT
                     ERROR RETURNS WILL NOT RESULT IN
                        TERMINATION OF EXECUTION

*************************************************************************************
 REVISION
   MATERIAL NUMBER      12
   MATERIAL IDENTIFICATION    STEEL
     NUMBER OF MATERIAL PROPERTY POINTS. . . .  1          INPUT CODE   I
     NUMBER OF PLASTIC PROPERTY POINTS. . . . -0
     MASS DENSITY. . . . . . . . . . . . . . .-0.

   MATERIAL PROPERTIES

                     YOUNG'S MODULI                              POISSON'S RATIOS
 TEMPERATURE           DIRECTIONS                                   DIRECTIONS
                XX              YY             ZZ              XY             YZ             ZX
    0.     0.300000E 08   C.3C000CE 08   0.300000E 08    0.300000E 00   0.300000E 00   0.300000E 00
                  THERMAL EXPANSION COEFFICIENTS                    RIGIDITY MODULI
 TEMPERATURE           DIRECTIONS                                   DIRECTIONS
                XX              YY             ZZ              XY             YZ             ZX
    0.     -0.            -0.            -0.             0.115385E 08   0.115385E 08   0.115385E 08
*************************************************************************************
```


FIGURE III-H.11 TITLE AND MATERIAL DATA OUTPUT,SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

9 REF. POINTS

NO. DIRECTIONS = 3 NO. DEGREES OF FREEDOM = 2

GRIDPOINT DATA
(IN RECTANGULAR COORDINATES)

POINT	X	Y	Z	TEMPERATURES	PRESSURES
1	0.0	0.0	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
2	0.16000000E 02	0.0	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
3	0.16000000E 02	0.16000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
4	0.0	0.16000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0

BOUNDARY CONDITION INFORMATION

NODES	DEGREES OF FREEDOM						NO. OF ONES	NO. OF TWOS
1	0	0	0	0	0	0	0	0
2	1	0	0	0	0	0	1	0
3	1	1	0	0	0	0	3	0
4	0	1	0	0	0	0	4	0
5	1	0	0	0	0	0	5	0
6	0	0	0	0	0	0	5	0
7	1	1	0	0	0	0	7	0
8	0	1	0	0	0	0	8	0
9	1	1	0	0	0	0	10	0

FIGURE III-H.12 GRIDPOINT DATA, BOUNDARY CONDITION AND FINITE ELEMENT DESCRIPTION OUTPUT, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

```
                                TOTAL NO. ELEMENTS =      2

ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NO.   --------GRID POINTS--------    EXTRA GRID PTS    ------SECTION PROPERTIES------
  1  20       12    0  0.0          2    6     1   2   4   5   9   8           1   2

MATERIAL NUMBER. . . . . . . . .    12
      MATERIAL IDENTIFICATION. . . .  STEEL
      ANALYSIS CAPABILITY. . . . . .  ISOTROPIC
      INPUT PRINT CODE . . . . . . .  1



      ELEMENT PRINT CODE . . . . . . . -1

INTERPOLATED MATERIAL PROPERTIES
      TEMPERATURE -        0.0
      YOUNG'S MODULI           0.30000000E 08      0.30000000E 08      0.30000000E 08
      POISSON'S RATIO          0.29999995E 00      0.29999995E 00      0.29999995E 00
      TH. EXP. COEF.           0.0                 0.0                 0.0
      RIGIDITY MODULI          0.11538460E 08      0.11538460E 08      0.11538460E 08

INTERPOLATED PLASTIC PROPERTIES
      NONE

PRE-STRAIN INPUT
      NONE

PRE-STRESS INPUT
      NONE

EXTERNAL INPUT
          0.99999964E-01     0.0          0.0          0.0          0.0

ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NO.   --------GRID POINTS--------    EXTRA GRID PTS    ------SECTION PROPERTIES------
  2  20       12    0  0.0          0    6     2   3   4   0   7   9           1   2         0.1000E 00   0.0        0.0
```

FIGURE III-H.12 GRIDPOINT DATA, BOUNDARY CONDITION AND FINITE ELEMENT DESCRIPTION OUTPUT, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

```
                                        EXTERNAL LOAD CONDITIONS   1

      LOAD NO.   1

         NUMBER OF LOADEC NODES    2           ELEMENT LOAD SCALAR =  0.
   2  0.66667E 03  0.           0.           0.           0.           0.
   3  0.4C00CE 03  0.           0.           0.           0.           0.

                                   TRANSFCRMED EXTERNAL ASSEMBLED LOAD COLUMN

                                                  54 X 1

      0.                 0.            0.            0.            0.            0.
      0.66667000E 03     0.            0.            0.            0.            0.
      C.40000000E 03     0.            0.            0.            0.            0.
      0.                 0.            0.            0.            0.            0.
      0.                 0.            0.            0.            0.            0.
      0.                 0.            0.            0.            0.            0.
      0.                 0.            0.            0.            0.            0.
      0.                 0.            0.            0.            0.            0.
      0.                 0.            0.            0.            0.            0.

                                       T-ZERO FOR STRUCTURE = -0.
```

FIGURE III-H.13 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT,
SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

MATRIX STIFF PAGE 1

CUTOFF = 0. SIZE 10 BY 10

		FORCE		FORCE		FORCE		FORCE		FORCE	
DISP.	1	1	0.293956E 07	2	0.906593E 06	3	-0.219780E 06	4	-0.357143E 06	5	-0.219780E 07
		6	0.100000E 00	7	0.714286E 06	8	0.109375E-01	9	-0.219780E 07	10	0.714285E 06
DISP.	2	1	0.906593E 06	2	0.293956E 07	3	0.714286E 06	4	0.192308E 06	6	-0.219780E 07
		7	-0.549451E 05	9	-0.219780E 07	10	-0.714286E 06				
DISP.	3	1	-0.219780E 06	2	0.714286E 06	3	0.151099E 07	4	0.192308E 06	6	0.549450E 05
		7	-0.769231E 06	9	-0.714286E 06	10	-0.769231E 06				
DISP.	4	1	-0.357143E 06	2	0.192308E 06	3	0.192308E 06	4	0.222527E 07	5	0.265625E-01
		6	-0.769231E 06	7	-0.769231E 06	8	-0.219780E 07	9	0.142857E 07	10	0.109375E 00
DISP.	5	1	-0.219780E 07	4	0.265625E-01	5	0.593406E 07	8	0.142857E 07	9	-0.153846E 07
		10	-0.142857E 07								
DISP.	6	1	0.100000E 00	2	-0.219780E 07	3	0.549450E 05	4	-0.769231E 06	6	0.593407E 07
		7	0.142857E 07	9	-0.153846E 07	10	-0.142857E 07				
DISP.	7	1	0.714286E 06	2	-0.549451E 05	3	-0.769231E 06	4	-0.769231E 06	6	0.142857E 07
		7	0.593407E 07	9	-0.142857E 07	10	-0.439560E 07				
DISP.	8	1	0.109375E-01	4	-0.219780E 07	5	0.142857E 07	8	0.593406E 07	9	-0.142857E 07
		10	-0.153846E 07								
DISP.	9	1	-0.219780E 07	2	-0.219780E 07	3	-0.714286E 06	4	0.142857E 07	5	-0.153846E 07
		6	-0.153846E 07	7	-0.142857E 07	8	-0.142857E 07	9	0.118681E 08	10	0.285714E 07
DISP.	10	1	0.714285E 06	2	-0.714286E 06	3	-0.769231E 06	4	0.109375E 00	5	-0.142857E 07
		6	-0.142857E 07	7	-0.439560E 07	8	-0.153846E 07	9	0.285714E 07	10	0.118681E 08

FIGURE III-H.14 REDUCED STIFFNESS MATRIX OUTPUT, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

GPRINT OF MATRIX LOADS (SET 1)

ROW	FX	FY	FZ	MX	MY	MZ
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.66666992E 03	0.0	0.0	0.0	0.0	0.0
3	0.40000000E 03	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE III-H.15 LOAD OUTPUT, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

DISPLACEMENT MATRIX FOR LOAD CONDITION 1

54 X 1

ROW	U	V	W	THETAX	THETAY	THETAZ
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.52188370E-03	0.0	0.0	0.0	0.0	0.0
3	0.18927772E-03	-0.13152210E-04	0.0	0.0	0.0	0.0
4	0.0	-0.14106605E-03	0.0	0.0	0.0	0.0
5	0.24360781E-03	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0
7	0.11873061E-03	-0.12144513E-03	0.0	0.0	0.0	0.0
8	0.0	-0.84205146E-04	0.0	0.0	0.0	0.0
9	0.18797964E-03	-0.79632737E-04	0.0	0.0	0.0	0.0

FIGURE III-H.16 DISPLACEMENT OUTPUT, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

REACTIONS AND INVERSE CHECK FOR LOAD CONDITION 1

ROW	FX	FY	FZ	MX	MY	MZ
1	-0.21504086E 03	0.37524796E 02	0.0	0.0	0.0	0.0
2	-0.36621094E-02	-0.12296735E 03	0.0	0.0	0.0	0.0
3	-0.14648437E-02	0.10681152E-03	0.0	0.0	0.0	0.0
4	-0.10886395E 03	0.80933375E-03	0.0	0.0	0.0	0.0
5	0.10768311E-02	0.85441895E 02	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0
7	0.36621094E-03	-0.24414062E-03	0.0	0.0	0.0	0.0
8	-0.74275610E 03	0.13732910E-03	0.0	0.0	0.0	0.0
9	0.99182129E-03	0.0	0.0	0.0	0.0	0.0

FIGURE III-H.17 REACTION OUTPUT, SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

S T R E S S E S   F O R   T H E   T R I A N G U L A R   T H I N   S H E L L   E L E M E N T

(STRESS POINT ONE EQUALS ELEMENT STRESSES EVALUATED AT THE CENTROID)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	20	1 2 4 5 9 8

APPARENT ELEMENT STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR NORMAL(QX)	NORMAL(QY)
1	0.7001200E 02	-0.5321210E 01	-0.4709600E 01	0.0	0.0	0.0	0.0	0.0
2	0.8064404E 02	-0.1407100E 02	0.1965420E-05	0.0	0.0	0.0	0.0	0.0
3	0.1100816E 03	-0.2967320E-01	-0.1604777E 02	0.0	0.0	0.0	0.0	0.0
4	0.4257193E 02	-0.1062050E 01	0.1910950E 01	0.0	0.0	0.0	0.0	0.0

ELEMENT APPLIED STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR NORMAL(QX)	NORMAL(QY)
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR NORMAL(QX)	NORMAL(QY)
1	0.7001200E 02	-0.5321210E 01	-0.4709600E 01	0.0	0.0	0.0	0.0	0.0
2	0.8064404E 02	-0.1407100E 02	0.1965420E-05	0.0	0.0	0.0	0.0	0.0
3	0.1100816E 03	-0.2967320E-01	-0.1604777E 02	0.0	0.0	0.0	0.0	0.0
4	0.4257193E 02	-0.1062050E 01	0.1910950E 01	0.0	0.0	0.0	0.0	0.0

FIGURE III-H.18 STRESS OUTPUT (ELEMENT NO. 1), SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

STRESSES FOR THE TRIANGULAR THIN SHELL ELEM. T

(STRESS POINT ONE EQUALS ELEMENT STRESSES EVALUATED AT THE CENTROID)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	2	20	2 3 4 0 7 9

APPARENT ELEMENT STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR NORMAL(QX)	NORMAL(QY)
1	0.553210E 02	0.532121E 01	-0.532126E 01	0.0	0.0	0.0	0.0	0.0
2	0.983024E 02	0.270247E 02	-0.121330E 02	0.0	0.0	0.0	0.0	0.0
3	0.249172E 02	0.900904E 01	-0.196865E 01	0.0	0.0	0.0	0.0	0.0
4	0.427433E 02	-0.160702E 02	-0.186227E 01	0.0	0.0	0.0	0.0	0.0

ELEMENT APPLIED STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR NORMAL(QX)	NORMAL(QY)
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR NORMAL(QX)	NORMAL(QY)
1	0.553210E 02	0.532121E 01	-0.532126E 01	0.0	0.0	0.0	0.0	0.0
2	0.983024E 02	0.270247E 02	-0.121330E 02	0.0	0.0	0.0	0.0	0.0
3	0.249172E 02	0.900904E 01	-0.196865E 01	0.0	0.0	0.0	0.0	0.0
4	0.427433E 02	-0.160702E 02	-0.186227E 01	0.0	0.0	0.0	0.0	0.0

FIGURE III-H.19 STRESS OUTPUT (ELEMENT NO. 2), SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

F O R C E S   F O R   T H E   T R I A N G U L A R   T H I N   S H E L L   E L E M E N T

(THE FIRST THREE POINTS ARE CORNER POINTS AND THE LAST THREE POINTS ARE MID-POINTS)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	20	1 2 4 5 9 8

APPARENT ELEMENT FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	-0.215040534E 03	0.373240826E 02	0.0	0.0	0.0	0.0
2	0.295309077E 03	-0.427942508E 02	0.0	0.0	0.0	0.0
3	0.311179992E 01	-0.496382252E 01	0.0	0.0	0.0	0.0
4	0.107603111E-02	0.854416946E 02	0.0	0.0	0.0	0.0
5	0.657140919E 03	-0.752079395E 02	0.0	0.0	0.0	0.0
6	-0.742755904E 03	0.0	0.0	0.0	0.0	0.0

ELEMENT APPLIED FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	-0.215040534E 03	0.373240826E 02	0.0	0.0	0.0	0.0
2	0.295309077E 03	-0.427942508E 02	0.0	0.0	0.0	0.0
3	0.311179992E 01	-0.496382252E 01	0.0	0.0	0.0	0.0
4	0.107603111E-02	0.854416946E 02	0.0	0.0	0.0	0.0
5	0.657140919E 03	-0.752079395E 02	0.0	0.0	0.0	0.0
6	-0.742755904E 03	0.0	0.0	0.0	0.0	0.0

FIGURE III-H.20 FORCE OUTPUT (ELEMENT NO. 1), SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

FORCES FOR THE TRIANGULAR THIN SHELL ELEMENT

(THE FIRST THREE POINTS ARE CORNER POINTS AND THE LAST THREE POINTS ARE MID-POINTS)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	2	20	2 3 4 0 7 9

APPARENT ELEMENT FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.37115597E 03	-0.80173060E 02	0.0	0.0	0.0	0.0
2	0.39999894E 03	0.10681152E-03	0.0	0.0	0.0	0.0
3	-0.11390157E 03	0.49659338E 01	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
5	0.36621094E-03	-0.24414062E-03	0.0	0.0	0.0	0.0
6	-0.65716095E 03	0.75207764E 02	0.0	0.0	0.0	0.0

ELEMENT APPLIED FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.37115597E 03	-0.80173060E 02	0.0	0.0	0.0	0.0
2	0.39999894E 03	0.10681152E-03	0.0	0.0	0.0	0.0
3	-0.11390157E 03	0.49659338E 01	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
5	0.36621094E-03	-0.24414062E-03	0.0	0.0	0.0	0.0
6	-0.65716095E 03	0.75207764E 02	0.0	0.0	0.0	0.0

FIGURE III-H.21 FORCE OUTPUT (ELEMENT NO. 2), SQUARE PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

I. SQUARE PLATE - NORMAL PRESSURE LOADING - (Triangular Thin Shell Idealization)

A simply supported isotropic square plate, under the action of normal pressure loading is shown in Figure III-I.1 along with its dimensions and pertinent material properties. The plate is idealized utilizing two triangular thin shell elements.

The preprinted input data forms associated with this example are shown in Figures III-I.2 through III-I.11.

In Figure III-I.5 (Gridpoint Coordinate Section) it is seen that only the grid points for the three corner points of each element are entered. The coordinates associated with mid-point nodes are calculated internally by the MAGIC System.

In Figure III-I.6 (Grid Point Pressure Section) the MODAL entry is used for the input pressure values.

This entry means that the normal pressures are acting at every grid point with a value of -1.0 psi. The sign of the pressure is minus since its direction is in the negative element Z_g direction.

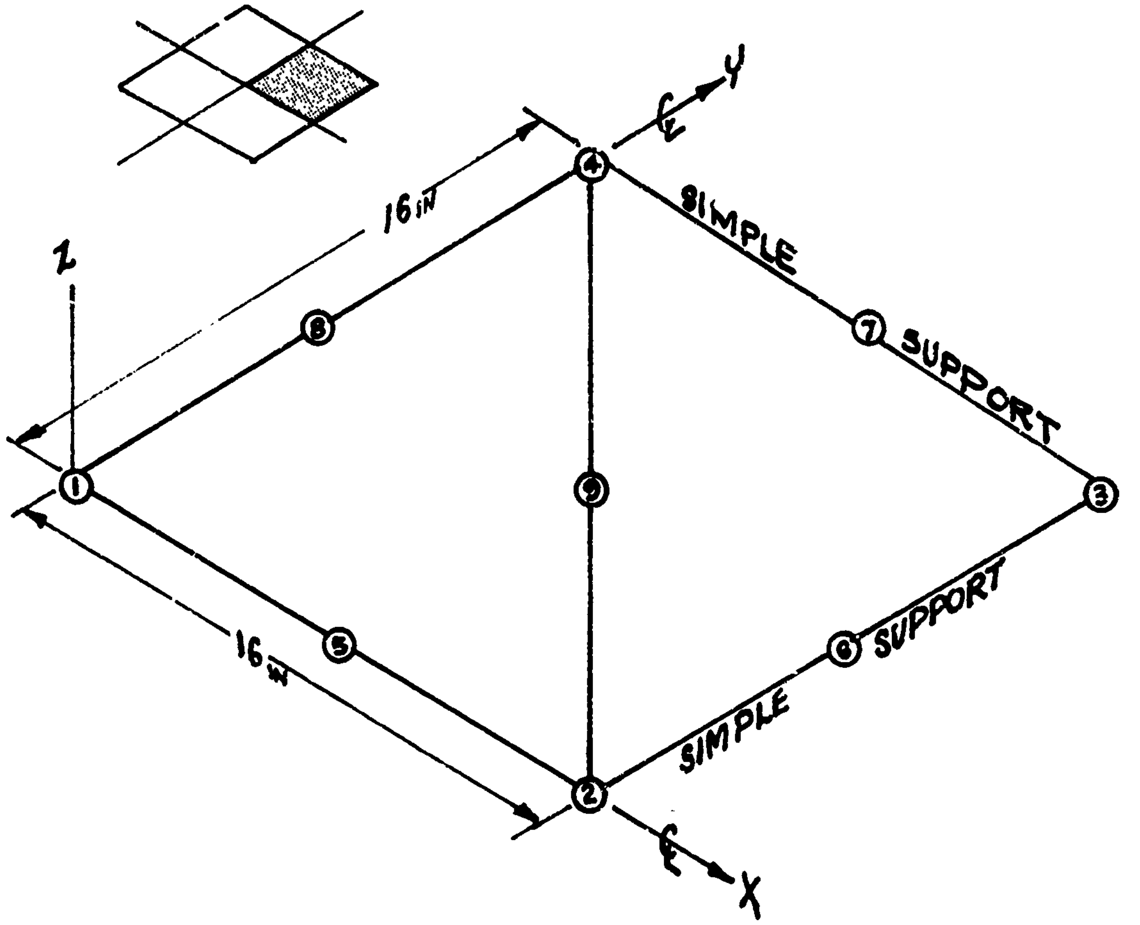
In Figure III-I.7 (Boundary Condition Section) it is instructive to note the nature of the boundary conditions which apply to each grid point (See Figure III-I.1). Let us examine the Listed Input (Exceptions to the MODAL card) first.

(1) Grid Point Number 1 (Center of plate) has an unknown displacement in the w direction, all others are zero due to symmetry.

(2) Grid Point Number 2 has an unknown rotation, θ_y. The others are zero due to the fact that grid point 2 is a point of simple support.

(3) Grid Point Number 3 has all degrees of freedom fixed. This is true because the simple supports meet at this point restricting rotation in the θ_x and θ_y directions.

(4) Grid Point Numbers 5 and 8 are repeated and also have all degrees of freedom fixed. These are mid-side nodes and the only possible degrees of freedom allowed are u, v, and θ_n (θ normal). Since this is a pure bending problem u and v are equal to zero. Since Grid Points 5 and 8 lie along symmetric boundaries, θ_n equals zero.



t = 0.10 INCH P = 1.0 PSI
E = 30. × 10^6 PSI μ = .30

FIGURE III - I.1 - Idealized Simply Supported Plate With Normal Pressure Loading (Triangular Thin Shell Idealization of One Quadrant)

The MODAL card is now examined for the remaining grid points. Since Grid Point Numbers 1, 2, 3, 5, and 8 were called out under Listed Input, the MODAL entry pertains to Grid Point Numbers 4, 6, 7, and 9.

(1) Grid Point Number 4 has an unknown rotation, θ_x. The others are zero since grid point 4 is a point of simple support.

(2) Grid points 6, 7, and 9 are mid-side nodes and the only possible degrees of freedom allowed are u, v, and θ_n (θ normal). Since this is a pure bending problem u and v are equal to zero. However, there is an unknown normal slope θ_n, associated with these grid points. The code (0, 1, 2) associated with these normal slope values is always entered in the θ_x location for consistency.

In Figure III-I.8 (External Loads Section) the following information is evident.

(1) One load condition is input

(2) The External Applied Load Scalar equals 1.0

(3) The MODAL option is employed and External Force and Moment values of 0.0 are entered in the appropriate locations. Since the Triangular Thin Shell Element is formulated with six degrees of Freedom per point, two external load cards per grid point are required.

The Element Applied Load Scalar was set equal to 1.0 because of the following:

Total Load = External Loads + EALS (Element Applied Loads)

Since the External Loads are equal to zero and the EALS = 1.0

Total Load = Element Applied Load

These are the correct loads since for this case the Element Applied Loads are equal to the normal pressure loads.

In Figure III-I.9 (Element Control Data Section) the following information is of importance.

(1) The numbers '1' and '2' are entered in locations 11 and 12 of the node point portion of the Element Control Section for Element Number 1. These two points define the direction of the (X) stress axis for Element Number 1. With this definition, the stresses in the other directions retain their proper orientation with respect to this axis.

(2) The numbers '4' and '3' are entered in locations 11 and 12 of the node point portion of the Element Control Section for Element Number 2. These two points define the direction of the (X) stress axis for Element Number 2.

It should be noted that the stress axis determination is element related and therefore if locations 11 and 12 are used for stress directions then each element must be considered separately. Node points related to each particular element must be used when determining stress directions utilizing locations 11 and 12.

In Figure III-I.10 (Element Input Section) only one item of information is entered in Location B of the MODAL section.

Location B - Flexural Thickness - $(t_f) = 0.10$

This MODAL entry signifies that this thickness applies to all elements used in this analysis.

BAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

R	E	P	O	R	T	(/)

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

1 2 3 4 5 6

T	I	T	L	E		(/)

7 8 9

	3	(/) NUMBER OF TITLE CARDS

Columns 1–72	
QUADRILATERAL THIN PLATE - SIMPLY SUPPORTED UNDER A UNIFØRM	(/)
NØRMAL LØADING ØF ØNE PSI - TWØ TRIANGULAR THIN SHELL ELEMENTS	(/)
USED IN THE IDEALIZATIØN	(/)
	(/)
	(/)
	(/)
	(/)
	(/)
	(/)

FIGURE III-I.2 TITLE INFORMATION, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

BAC 1616-1

M	A	T	E	R	
1	2	3	4	5	6

(/)

7	8	9
		1

No. of Requests (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MATERIAL TAPE INPUT

Request Number	MATERIAL NUMBER	Lock Code	MATERIAL IDENTIFICATION	Isotropic	Orthotropic	Plastic Isotropic	Plastic Orthotropic	Add Plastic	Delete Material	Print Tape	Print Mat'l. Table	Print Mat'l. Summary	Number of Mat'l. Pts.	Number of Plastic Pts.	MASS DENSITY	
7–9	10–15	16–17	18–41	42	43	44	45	46	47	48	49	50	51–52	53–54	55–64	
1	1	2	TU STEEL-E=30.0E6, MU=0.30	X							X		1		0.0005	(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE (13–22)	Direction	YOUNGS MODULI (23–32)	Direction	POISSONS RATIOS (33–42)	Direction	COEF. OF THERMAL EXPANSION (43–52)	Direction	RIGIDITY MODULI (53–62)	
0.0	E_x	30.0 E6	ν_{xy}	0.30	α_x	8.50 E-6	G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

FIGURE III-I.3 MATERIAL TAPE INPUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

Request	Columns	Entry
	1–6	S Y S T E M (/)
1. Number of System Grid Points	1–6	9
2. Number of Input Grid Points	7–12	4
3. Number of Degrees of Freedom/Grid Point	13–14	6
4. Number of Load Conditions	15–16	1
5. Number of Initially Displaced Grid Points	17–22	
6. Number of Prescribed Displaced Grid Points	23–28	
7. Number of Grid Point Axes Transformation Systems	29–30	
8. Number of Elements	31–36	2
9. Number of Requests and/or Revisions of Material Tape.	37–38	1
10. Number of Input Boundary Condition Points	39–44	5
11. T_0 For Structure (With Decimal Point)	45–52	0 0 (/)

FIGURE III-I.4 SYSTEM CONTROL INFORMATION, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

BAC 1622

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6
C	O	O	R	D	

(/)

GRIDPOINT COORDINATE

COORD. INPUT	$\not{b}$
SYSTEM: RECTANGULAR	R/Δ
SYSTEM: CYLINDRICAL	C
SYSTEM: SPHERICAL	S

Δ = BLANK

$ (cols 5–6)	Grid Point Number (cols 7–12)	DIRECTIONS X – R (cols 13–22)	DIRECTIONS Y – Θ (cols 23–32)	DIRECTIONS Z – Z (cols 33–42)	
	1	0.0	0.0	0.0	(/)
	2	16.0	0.0	0.0	(/)
	3	16.0	16.0	0.0	(/)
	4	0.0	16.0	0.0	(/)

FIGURE III-I.5 GRIDPOINT COORDINATES, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

GRID POINT PRESSURES

1	2	3	4	5	6	
P	R	E	S	S		(/)

1 2 3 4 5 6	PRESSURES		
	P_1	P_2	P_3
	13 4 5 6 7 8 9 20 1 2	23 4 5 6 7 8 9 30 1 2	33 4 5 6 7 8 9 40 1 2
M O D A L	-1.0		

Grid Point Number	Repeat	P_1	P_2	P_3	
7 8 9 10 11	12	13 4 5 6 7 8 9 20 1 2	23 4 5 6 7 8 9 30 1 2	33 4 5 6 7 8 9 40 1 2	
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)

FIGURE III-I.6 GRIDPOINT PRESSURES, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE -	0 - No Displacement Allowed 1 - Unknown Displacement 2 - Known Displacement

1	2	3	4	5	6	
B	O	U	N	D		(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	θx	θy	θz	1	2	3	
13	14	15	16	17	18	19	20	21	
0	0	0	1	0	0				(/)

LISTED INPUT

Grid Point Number					Repeat										
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
				1		0	0	1	0	0	0				(/)
				2		0	0	0	0	1	0				(/)
				3		0	0	0	0	0	0				(/)
				5	X										(/)
				8	X										(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)

FIGURE III-I.7 BOUNDARY CONDITIONS SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

BAC 1627

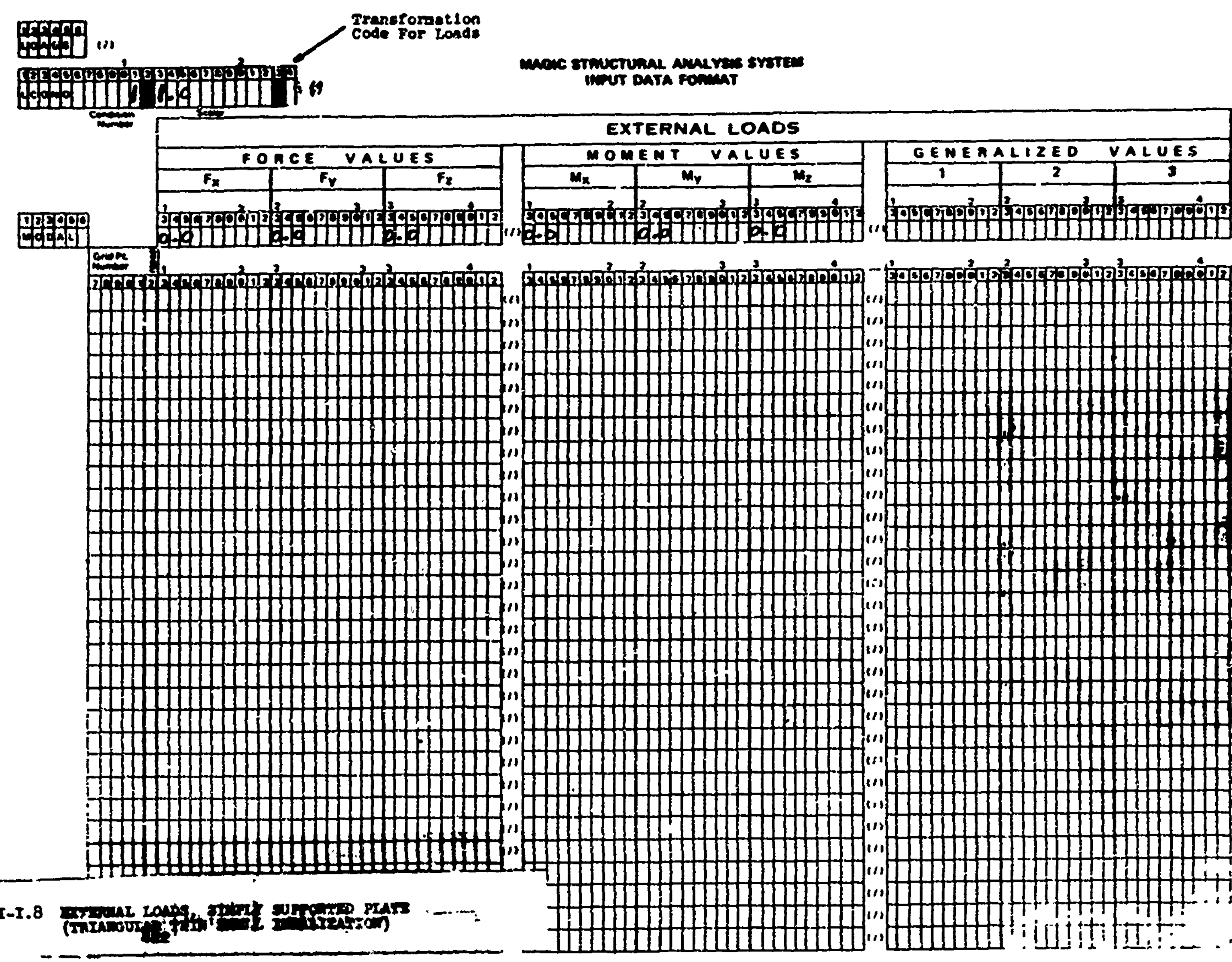


FIGURE III-I.8 EXTERNAL LOADS, SIMPLY SUPPORTED PLATE
(TRIANGULAR THIN SHELL IDEALIZATION)

ELEM (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

Element Number (7-10)	Plug No. (11-12)	Material Number (13-18)	Interpolate Option (19)	Material Temperature (20-27)	Repeat Elem. Matrices (28)	Elem. Input (29)	Print: Print (30)	Print: Elem. Mat. (31)	Print: Full (32)	Number of Input Nodes (33-34)	Suppress Pressures (35)	Node Points 1	2	3	4	5	6	7	8	9	10	11	12
1	20	12				X			X	6		1	2	4	5	9	8					1	2
2	20	12				X				6		2	3	4	6	7	9					4	3

FIGURE III-I.9 ELEMENT CONTROL DATA, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

BAC 1629-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

EXTERN (/)

ELEMENT INPUT

	A	B	C	D	E	F
MODAL	0.0	0.10	0.0	0.0	0.0	

Element Number	Repeat	A	B	C	D	E	F

FIGURE III-I.10 ELEMENT INPUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

CHECK OR END CARD

C	H	E	C	K
1	2	3	4	5

(/)

E	N	D
1	2	3

(/)

FIGURE III-I.11 END CARD, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

The output supplied by the MAGIC System for the simply supported isotropic square plate subjected to a normal pressure load and idealized using two triangular thin shell elements is as follows:

Figures III-I.12 through III-I.14 display the output from the Structural Systems Monitor. These figures record the input data pertinent to the problem being solved.

The Grid Point Data Information is shown in Figure III-I.13. Note that pressures of -1.0 psi are applied at each grid point. The finite element information is also shown in Figure III-I.13. Under the section titled External Input, the second entry has a numerical value of 0.09999999. This value is equal to the flexural thickness of the plate being analyzed.

Figure III-I.14 displays the Transformed External Assembled Load Column. Note that these loads are all equal to zero since input pressures are element applied loads.

MAGIC System output of final results is shown in Figures III-I.15 thru III-I.22.

Figure III-I.15 shows the assembled and reduced stiffness matrix. The stiffness matrix is read row-wise and only non-zero terms are displayed. The ordering of the stiffness matrix is consistent with that of the boundary conditions shown in Figure III-I.13. For this case the displacement vector is ordered as follows:

$$\{q\}^T = \lfloor w_1, \theta_{y2}, \theta_{x4}, \theta_{n6}, \theta_{n7}, \theta_{n9} \rfloor$$

Where θ_{ni} = normal slope at node point i

Figure II-I.16 displays the element applied loads (GPRINT OF MATRIX FTELA) which arise from the normal pressure loading of one psi. The loads are output against grid point number and note that grid points 5 thru 9 are associated with mid-side nodes. This being the case, the load (M_X) associated with these node points corresponds to the normal slope degree-of-freedom (θ_n).

Displacements are presented in Figure III-I.17. Displacements are output against node point number and are referenced to the Global Axis unless otherwise indicated.

Reactions are presented in Figure III-I.18. The reactions are output against node point number and are referenced to the Global Axis.

Stress resultants for the Triangular Thin Shell Element are presented in Figures III-I.19 and III-I.20. Eight stress resultants are evaluated at each corner point of the triangle and also at its centroid, yielding a total of 32 stress resultants per element.

The stress resultants for the triangular thin shell were explicitly defined in Section III-H (Square Plate - Parabolic Membrane Loading). Sketches were also provided to facilitate proper interpretation of the stress resultants.

The stress vector is in general referenced to the element coordinate system. For the quadrilateral or triangular thin shell elements, however, the User has the option of specifying material or stress axes in order to effectively define stress output direction. This is accomplished by utilizing locations 9 and 10 or 11 and 12 of the node point portion of the Element Control Section. In this particular problem the numbers '1' and '2' were entered in locations 11 and 12 of the node point portion of the Element Control Section for Element Number 1 and for Element Number 2 the numbers '4' and '3' were entered in locations 11 and 12. These two points define the X direction of the stress axis (Positive X from node point 1 to node point 2 for element number 1 and positive X from node point 4 to node point 3 for element number 2). These axes of reference then become the reference stress axes for elements 1 and 2 respectively.

Figure III-I.19 presents the stress resultants for Element No. 1. Stress points 1, 2, 3, and 4 correspond to the following:

Stress point 1 equals the element stresses evaluated at the centroid. Stress points 2, 3, and 4 correspond to element corner points 1, 2 and 4 respectively.

Figure III-I.20 presents the stress resultants for Element No. 2. Stress points 1, 2, 3, and 4 correspond to the following:

Stress point 1 equals the element stresses evaluated at the centroid. Stress points 2, 3, and 4 correspond to element corner points 2, 3, and 4 respectively.

It is to be remembered for the triangular thin shell element that for each element, the centroidal value of the stress resultants for that element are the first to be printed. (In the general case the node point stresses are printed and then the centroidal stresses.)

Figures III-I.21 and III-I.22 present the element forces for the two triangular thin shell elements used in this application. These forces are defined with respect to the Global Coordinate System. In Figure III-I.21, Force Points 1 thru 3 correspond to element corner points 1, 2 and 4. Force points 4 thru 6 correspond to element mid-points 5, 9 and 8. Note that the mid-side nodes have allowable degrees-of-freedom equal to U, V, and normal slope (θ_n). Therefore, in a flexture problem, the moment at any mid-side node is associated with the normal slope.

The forces for Element No. 2, shown in Figure III-I.22, are interpreted in an analogous manner to those for Element No. 1.

```
SIMPLY SUPPORTEC ISCTROPIC SQUARE PLATE SUBJECTED TO A

UNIFORM NORMAL PRESSURE LOAD OF 1 PSI- TWO TRIANGULAR

THIN SHELL ELEMENTS USED IN THE IDEALIZATION

                         REVISIONS OF MATERIAL TAPE

                       ASTERISK (*) PRECEEDING MATERIAL
                       IDENTIFICATION INDICATES THAT INPUT
                       ERROR RETURNS WILL NOT RESULT IN
                           TERMINATION OF EXECUTION

***********************************************************************************************

REVISION
  MATERIAL NUMBER      12                                  INPUT CODE   1
  MATERIAL IDENTIFICATION     STEEL
    NUMBER OF MATERIAL PROPERTY POINTS. . . .  1
    NUMBER OF PLASTIC PROPERTY POINTS . . . . -0
    MASS DENSITY. . . . . . . . . . . . . . -0.

  MATERIAL PROPERTIES
                          YOUNG'S MODULI                                          POISSON'S RATIOS

                           DIRECTIONS                                               DIRECTIONS

TEMPERATURE          XX               YY               ZZ                XY               YZ               ZX
    0.       0.300000E 08     0.300000E 08     0.300000E 08      0.300000E 00     0.300000E 00     0.300000E 00
                    THERMAL EXPANSION COEFFICIENTS                                RIGIDITY MODULI

                           DIRECTIONS                                               DIRECTIONS

TEMPERATURE          XX               YY               ZZ                XY               YZ               ZX
    0.          -0.              -0.              -0.            0.115385E 08     0.115385E 08     0.115385E 08

***********************************************************************************************
```

FIGURE III-I.12 TITLE AND MATERIAL DATA OUTPUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

9 REF. POINTS

NO. DIRECTIONS = 3 NO. DEGREES OF FREEDOM = 2

GRIDPOINT DATA
(IN RECTANGULAR COORDINATES)

POINT	X	Y	Z	TEMPERATURES	PRESSURES
1	0.0	0.0	0.0	0.0	-0.10000000E 01
				0.0	0.0
				0.0	0.0
2	0.16000000E 02	0.0	0.0	0.0	-0.10000000E 01
				0.0	0.0
				0.0	0.0
3	0.16000000E 02	0.16000000E 02	0.0	0.0	-0.10000000E 01
				0.0	0.0
				0.0	0.0
4	0.0	0.16000000E 02	0.0	0.0	-0.10000000E 01
				0.0	0.0
				0.0	0.0

BOUNDARY CONDITION INFORMATION

NODES	DEGREES OF FREEDOM						NO. OF ONES	NO. OF TWOS
1	0	0	1	0	0	0	1	0
2	0	0	0	0	1	0	2	0
3	0	0	0	0	0	0	2	0
4	0	0	0	1	0	0	3	0
5	0	0	0	0	0	0	3	0
6	0	0	0	1	0	0	4	0
7	0	0	0	1	0	0	5	0
8	0	0	0	0	0	0	5	0
9	0	0	0	1	0	0	6	0

FIGURE III-I.13 GRIDPOINT DATA, BOUNDARY CONDITION AND FINITE ELEMENT DESCRIPTION OUTPUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

```
                                        TOTAL NO. ELEMENTS =      2

ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NO.   --------GRID POINTS--------    EXTRA GRID PTS    ------SECTION PROPERTIES------
  1  20       12    0  0.0          2    6     1   2   4   5   9   8           0   0   1   2

MATERIAL NUMBER. . . . . . . .    12
      MATERIAL IDENTIFICATION. . . .   STEEL
      ANALYSIS CAPABILITY. . . . . .  ISOTROPIC
      INPUT PRINT CODE . . . . . . .  1


      ELEMENT PRINT CODE . . . . . . . -1

INTERPOLATED MATERIAL PROPERTIES
      TEMPERATURE -       0.0
      YOUNG'S MODULI          0.30000000E 08     0.30000000E 08     0.30000000E 08
      POISSON'S RATIO         0.29999995E 00     0.29999995E 00     0.29999995E 00
      TH. EXP. COEF.          0.0                0.0                0.0
      RIGIDITY MODULI         0.11538468E 08     0.11538468E 08     0.11538468E 08

INTERPOLATED PLASTIC PROPERTIES
      NONE

PRE-STRAIN INPUT
      NONE

PRE-STRESS INPUT
      NONE

EXTERNAL INPUT
          0.0                 0.99999964E-01     0.0                0.0                0.0

ELEM TYPE  MAT.NO. CODE   TEMP.   PRNT  NO.   --------GRID POINTS--------    EXTRA GRID PTS    ------SECTION PROPERTIES------
  2  20       12    0  0.0          0    6     2   3   4   6   7   9           0   0   4   3   0.0          0.1000E 00    0.0
```

FIGURE III-I.13 GRIDPOINT DATA, BOUNDARY CONDITION AND FINITE ELEMENT DESCRIPTION OUTPUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

EXTERNAL LOAD CONDITIONS 1

LOAD NO. 1

NUMBER OF LOADED NODES 9

ELEMENT LOAD SCALAR = 0.10000000E 01

1	0.	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.	0.
3	0.	0.	0.	0.	0.	0.
4	0.	0.	0.	0.	0.	0.
5	0.	0.	0.	0.	0.	0.
6	0.	0.	0.	0.	0.	0.
7	0.	0.	0.	0.	0.	0.
8	0.	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.	0.

TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN

54 X 1

0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.

T-ZERO FOR STRUCTURE = 0.

FIGURE III-I.14 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

MATRIX STIFF PAGE 1

CUTOFF = 0. SIZE 6 BY 6

	FORCE		FORCE		FORCE		FORCE		FORCE	
DISP. 1	1	0.665350E 03	2	-0.123054E 04	3	0.123054E 04	6	-0.404708E 04		
DISP. 2	1	-0.123054E 04	2	0.158730E 05	3	-0.106074E 05	4	-0.120574E 05	5	-0.747863E 04
	6	-0.841794E 04								
DISP. 3	1	0.123054E 04	2	-0.106074E 05	3	0.158730E 05	4	0.747863E 04	5	0.120574E 05
	6	0.841793E 04								
DISP. 4	2	-0.120574E 05	3	0.747863E 04	4	0.244200E 05	5	-0.122100E 04	6	0.112239E 05
DISP. 5	2	-0.747863E 04	3	0.120574E 05	4	-0.122100E 04	5	0.244200E 05	6	0.112239E 05
DISP. 6	1	-0.404708E 04	2	-0.841794E 04	3	0.841793E 04	4	0.112239E 05	5	0.112239E 05
	6	0.610501E 05								

FIGURE III-I.15 REDUCED STIFFNESS MATRIX OUTPUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

GPRINT OF MATRIX FTELA (SET 1)

ROW	FX	FY	FZ	MX	MY	MZ
1	0.0	0.0	-0.46933273E 02	-0.79644455E 02	0.75644058E 02	0.0
2	0.0	0.0	-0.81066299E 02	-0.21617734E 03	-0.21617746E 03	0.0
3	0.0	0.0	-0.46933151E 02	0.79643890E 02	-0.75644241E 02	0.0
4	0.0	0.0	-0.81066208E 02	0.21617700E 03	0.21617770E 03	0.0
5	0.0	0.0	0.0	-0.45510880E 02	0.0	0.0
6	0.0	0.0	0.0	-0.45510849E 02	0.0	0.0
7	0.0	0.0	0.0	-0.45511398E 02	0.0	0.0
8	0.0	0.0	0.0	0.45511444E 02	0.0	0.0
9	0.0	0.0	0.0	-0.12207031E-03	0.0	0.0

FIGURE III-I.16 ELEMENT APPLIED LOAD OUTPUT, SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

DISPLACEMENT MATRIX FOR LOAD CONDITION 1

54 X 1

ROW	U	V	W	THETAX	THETAY	THETAZ
1	0.0	0.0	-0.13527546E 01	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	-0.18097317E 00	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.18097043E 00	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	-0.10561597E 00	0.0	0.0
7	0.0	0.0	0.0	-0.10561484E 00	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	-0.10974854E 00	0.0	0.0

FIGURE III-I.17 DISPLACEMENT OUTPUT, SIMPLY SUPPORTED PLATE
(TRIANGULAR THIN SHELL IDEALIZATION)

REACTIONS AND INVERSE CHECK FOR LOAD CONDITION 1

ROW	FX	FY	FZ	MX	MY	MZ
1	0.0	0.0	0.13885498E-02	-0.10729866E 03	0.10730394E 03	0.0
2	0.0	0.0	0.10411229E 03	0.38258545E 03	0.16784668E-02	0.0
3	0.0	0.0	0.47772751E 02	-0.17323959E 03	0.17323970E 03	0.0
4	0.0	0.0	0.10411420E 03	-0.24414062E-03	-0.38259253E 03	0.0
5	0.0	0.0	0.0	-0.48422070E 03	0.0	0.0
6	0.0	0.0	0.0	-0.13580322E-02	0.0	0.0
7	0.0	0.0	0.0	-0.56457520E-03	0.0	0.0
8	0.0	0.0	0.0	0.48420557E 03	0.0	0.0
9	0.0	0.0	0.0	-0.15502930E-01	0.0	0.0

FIGURE III-I.18 REACTION OUTPUT, SIMPLY SUPPORTED PLATE
(TRIANGULAR THIN SHELL IDEALIZATION)

S T R E S S E S   F O R   T H E   T R I A N G U L A R   T H I N   S H E L L   E L E M E N T

(STRESS POINT ONE EQUALS ELEMENT STRESSES EVALUATED AT THE CENTROID)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	20	1 2 4 5 5 8

APPARENT ELEMENT STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR NORMAL(QX)	NORMAL(QY)
1	0.0	0.0	0.0	-0.394007E 02	-0.360874E 02	-0.153317E-04	-0.644942E 01	-0.107817E-03
2	0.0	0.0	0.0	-0.324411E 02	-0.324416E 02	-0.426079E-03	-0.644942E 01	-0.107817E-03
3	0.0	0.0	0.0	-0.450118E 02	-0.450113E 02	0.179758E 01	-0.644942E 01	-0.197817E-03
4	0.0	0.0	0.0	-0.119942E 02	-0.318744E 02	-0.925273E 01	-0.644942E 01	-0.107817E-03

ELEMENT APPLIED STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR NORMAL(QX)	NORMAL(QY)
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR NORMAL(QX)	NORMAL(QY)
1	0.0	0.0	0.0	-0.394007E 02	-0.360874E 02	-0.153317E-04	-0.644942E 01	-0.107817E-03
2	0.0	0.0	0.0	-0.324411E 02	-0.324416E 02	-0.426079E-03	-0.644942E 01	-0.107817E-03
3	0.0	0.0	0.0	-0.450118E 02	-0.450113E 02	0.179758E 01	-0.644942E 01	-0.107817E-03
4	0.0	0.0	0.0	-0.119942E 02	-0.318744E 02	-0.925273E 01	-0.644942E 01	-0.107817E-03

FIGURE III-1.19 STRESS OUTPUT (ELEMENT NO. 1), SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

S T R E S S E S   F O R   T H E   T R I A N G U L A R   T H I N   S H E L L   E L E M E N T

(STRESS POINT ONE EQUALS ELEMENT STRESSES EVALUATED AT THE CENTROID)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	2	20	2 3 4 6 7 9

APPARENT ELEMENT STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR NORMAL(QX)	NORMAL(QY)
1	0.0	0.0	0.0	-0.249948E 02	0.698339E 01	-0.119919E 02	-0.818033E 00	0.166364E 01
2	0.0	0.0	0.0	-0.237233E 02	-0.179946E 02	-0.137144E 02	-0.818033E 00	0.166364E 01
3	0.0	0.0	0.0	-0.232203E 02	0.232202E 02	-0.174153E 02	-0.818033E 00	0.166364E 01
4	0.0	0.0	0.0	-0.270230E 02	0.368179E 01	-0.365906E 01	-0.818033E 00	0.166364E 01

ELEMENT APPLIED STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR NORMAL(QX)	NORMAL(QY)
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

NET ELEMENT STRESSES

STRESS POINT	MEMBRANE STRESS RESULTANTS NORMAL(NX)	NORMAL(NY)	SHEAR(NXY)	FLEXURAL MOMENTS NORMAL(MX)	NORMAL(MY)	TORQUE(MXY)	SHEAR NORMAL(QX)	NORMAL(QY)
1	0.0	0.0	0.0	-0.249948E 02	0.698339E 01	-0.119919E 02	-0.818033E 00	0.166364E 01
2	0.0	0.0	0.0	-0.237233E 02	-0.179946E 02	-0.137144E 02	-0.818033E 00	0.166364E 01
3	0.0	0.0	0.0	-0.232203E 02	0.232202E 02	-0.174153E 02	-0.818033E 00	0.166364E 01
4	0.0	0.0	0.0	-0.270230E 02	0.368179E 01	-0.365906E 01	-0.818033E 00	0.166364E 01

FIGURE III-I.20 STRESS OUTPUT (ELEMENT NO. 2), SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

F O R C E S   F O R   T H E   T R I A N G U L A R   T H I N   S H E L L   E L E M E N T

(THE FIRST THREE POINTS ARE CORNER POINTS AND THE LAST THREE POINTS ARE MID-POINTS)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	20	1 2 4 5 5 8

APPARENT ELEMENT FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.0	0.0	-0.46931885E 02	-0.18694312E 03	0.18694800E 03	0.0
2	0.0	0.0	0.23465317E 02	0.19395288E 03	-0.31957520E 02	0.0
3	0.0	0.0	0.23466446E 02	0.31946289E 02	-0.19395801E 03	0.0
4	0.0	0.0	0.0	-0.52973169E 03	0.0	0.0
5	0.0	0.0	0.0	-0.16306812E 03	0.0	0.0
6	0.0	0.0	0.0	0.52971704E 03	0.0	0.0

ELEMENT APPLIED FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.0	0.0	-0.46933273E 02	-0.79644455E 02	0.79644050E 02	0.0
2	0.0	0.0	-0.40533127E 02	-0.73955921E 02	-0.14222202E 03	0.0
3	0.0	0.0	-0.40533112E 02	0.14222192E 03	0.73955353E 02	0.0
4	0.0	0.0	0.0	-0.45510800E 02	0.0	0.0
5	0.0	0.0	0.0	-0.32181015E 02	0.0	0.0
6	0.0	0.0	0.0	0.45511444E 02	0.0	0.0

NET ELEMENT FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.0	0.0	0.13885498E-02	-0.10729866E 03	0.10730394E 03	0.0
2	0.0	0.0	0.63998444E 02	0.26790820E 03	0.11024490E 03	0.0
3	0.0	0.0	0.63999557E 02	-0.11027563E 03	-0.26791333E 03	0.0
4	0.0	0.0	0.0	-0.48422070E 03	0.0	0.0
5	0.0	0.0	0.0	-0.13088710E 03	0.0	0.0
6	0.0	0.0	0.0	0.48420557E 03	0.0	0.0

FIGURE III-I.21 FORCE OUTPUT (ELEMENT NO. 1), SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

FORCES FOR THE TRIANGULAR THIN SHELL ELEMENT

(THE FIRST THREE POINTS ARE CORNER POINTS AND THE LAST THREE POINTS ARE MID-POINTS)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	2	20	2 3 4 6 7 9

APPARENT ELEMENT FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.0	0.0	-0.41944825E 00	-0.27544434E 02	-0.18421851E 03	0.0
2	0.0	0.0	0.83959961E 00	-0.93595703E 02	0.93595459E 02	0.0
3	0.0	0.0	-0.41838074E 00	0.18423071E 03	0.27543213E 02	0.0
4	0.0	0.0	0.0	-0.45512207E 02	0.0	0.0
5	0.0	0.0	0.0	-0.45511963E 02	0.0	0.0
6	0.0	0.0	0.0	0.16305591E 03	0.0	0.0

ELEMENT APPLIED FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.0	0.0	-0.40533173E 02	-0.14222182E 03	-0.73955444E 02	0.0
2	0.0	0.0	-0.46933151E 02	0.79643890E 02	-0.79644241E 02	0.0
3	0.0	0.0	-0.40533096E 02	0.73955078E 02	0.14222235E 03	0.0
4	0.0	0.0	0.0	-0.45510849E 02	0.0	0.0
5	0.0	0.0	0.0	-0.45511398E 02	0.0	0.0
6	0.0	0.0	0.0	0.32100893E 02	0.0	0.0

NET ELEMENT FORCES

POINT	FORCES FX	FORCES FY	FORCES FZ	MOMENTS MX	MOMENTS MY	MOMENTS MZ
1	0.0	0.0	0.40113724E 02	0.11467738E 03	-0.11026306E 03	0.0
2	0.0	0.0	0.47772751E 02	-0.17323959E 03	0.17323970E 03	0.0
3	0.0	0.0	0.40114716E 02	0.11027563E 03	-0.11467914E 03	0.0
4	0.0	0.0	0.0	-0.13580322E-02	0.0	0.0
5	0.0	0.0	0.0	-0.56457520E-03	0.0	0.0
6	0.0	0.0	0.0	0.13087502E 03	0.0	0.0

FIGURE III-I.22 FORCE OUTPUT (ELEMENT NO. 2), SIMPLY SUPPORTED PLATE (TRIANGULAR THIN SHELL IDEALIZATION)

J. THICK WALLED DISK - THERMAL LOAD
(Trapezoidal Cross-Section Ring Idealization)

A thick walled disk under the influence of a radially varying thermal loading is shown in Figure III-J.1, along with its dimensions and pertinent material properties. This disk is idealized using trapezoidal cross-section ring elements. The preprinted input data forms associated with this problem are shown in Figures III-J.2 through III-J.10.

In Figure III-J.3 (Material Tape Input Section) note that 2 material (temperature) points are entered for the material in question. A linear interpolation for material properties is performed for temperatures which fall between these two temperature points.

In Figure III-J.6 (Grid Point Temperature Section) it is instructive to note the use of the Repeat Option. Grid Point 12 has the same temperature as Grid Point 1, therefore the Repeat option is employed by placing an 'X' in Column 12 opposite the entry for Grid Point Number 12. This same procedure is also used for Grid Points 2, 3, 4, and 5. Note that the Grid Points are not entered sequentially allowing the use of the Repeat option. It should also be noted that the temperature values are entered in Columns 13-22.

In Figure III-J.7 (Boundary Condition Section) it is instructive to note the use of the MODAL option. There is only 1 exception to the MODAL card and this is Grid Point Number 12. This exception must be called out on the System Control Information Data Form (Figure III-J.4).

In Figure III-J.8 (External Loads Section) the following information is evident.

(1) One load condition is input.

(2) The External Applied Load Scalar equals 1.0.

(3) At Grid Point 1 loads of 0.0 are entered in the locations corresponding to F_x, F_y and F_z. Note that this is the only entry required (the Moment and Generalized Values are ignored) since the Trapezoidal Cross-section ring has three degrees of freedom per point thus requiring only one external load card per grid point.

$E = 1.8 \times 10^7$ PSI
$\mu = 0.30$
$\alpha = 0.10 \times 10^{-6}$

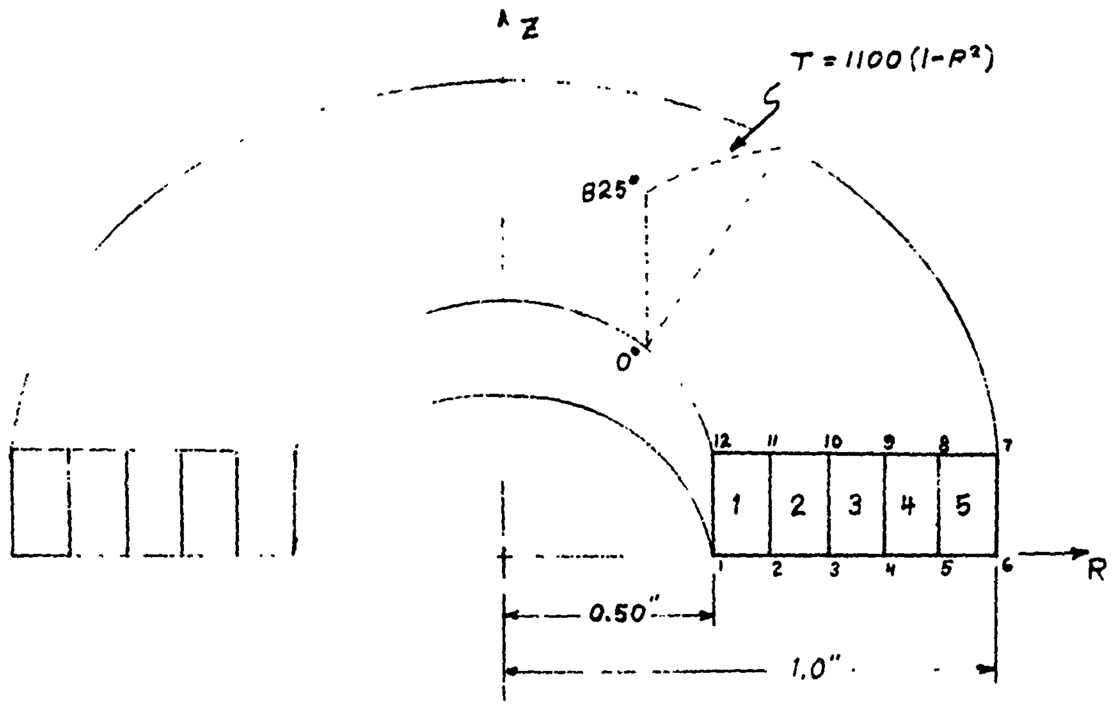


FIGURE III-J.1 IDEALIZED THICK WALLED DISK
(TRAPEZOIDAL RING)

BAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

REPORT (/)

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

1 2 3 4 5 6

TITLE (/)

7 8 9

3 (/) NUMBER OF TITLE CARDS

TRAPEZOIDAL RING PROBLEM (/

THICK WALLED DISK UNDER THERMAL LOADING PLANE STRESS FORMULATION (/

REFERENCE WANG APPLIED ELASTICITY PAGE 70 (/

Figure III-J.2 Title Information, Thick Walled Disk

BAC 1516-1

M	A	T	E	R		(/)
1	2	3	4	5	6	

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

		1	(/)
7	8	9	

No. of Requests

MATERIAL TAPE INPUT

Request Number (7–9)	MATERIAL NUMBER (10–15)	Lock Code (16–17)	MATERIAL IDENTIFICATION (18–41)	Isotropic (42)	Orthotropic (43)	Plastic Isotropic (44)	Plastic Orthotropic (45)	Add Plastic (46)	Delete Material (47)	Print Tape (48)	Print Mat'l. Table (49)	Print Mat'l. Summary (50)	Number of Mat'l. Pts. (51–52)	Number of Plastic Pts. (53–54)	MASS DENSITY (55–64)	
1	1	28T	MATL. FOR BIF TEST	X									2		0.0	(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE (13–22)	Direction	YOUNGS MODULI (23–32)	Direction	POISSONS RATIOS (33–42)	Direction	COEF. OF THERMAL EXPANSION (43–52)	Direction	RIGIDITY MODULI (53–62)	
0.0	E_x	0.180 E8	ν_{xy}	0.30	α_x	0.100 E-6	G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
1500.0		0.180 E8		0.30		0.100 E-6			(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

Figure III-J.3 Material Tape Input, Thick Walled Disk

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

	Entry	Columns
	S Y S T E M (/)	1 2 3 4 5 6
1. Number of System Grid Points	12	1 2 3 4 5 6
2. Number of Input Grid Points	12	7 8 9 10 11 12
3. Number of Degrees of Freedom/Grid Point	3	13 14
4. Number of Load Conditions	1	15 16
5. Number of Initially Displaced Grid Points		17 18 19 20 21 22
6. Number of Prescribed Displaced Grid Points		23 24 25 26 27 28
7. Number of Grid Point Axes Transformation Systems		29 30
8. Number of Elements	5	31 32 33 34 35 36
9. Number of Requests and/or Revisions of Material Tape.	1	37 38
10. Number of Input Boundary Condition Points	1	39 40 41 42 43 44
11. T_o For Structure (With Decimal Point)	0.0 (/)	45 46 47 48 49 50 51 52

Figure III-J.4 System Control Information, Thick Walled Disk

SAC 1032

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6
C	O	O	R	D	

(/)

GRIDPOINT COORDINATE

SYSTEM		
	COORD. INPUT	S
SYSTEM	RECTANGULAR	R/Δ
SYSTEM	CYLINDRICAL	C
SYSTEM	SPHERICAL	S

Δ = BLANK

S	Grid Point Number	DIRECTIONS X – R	DIRECTIONS Y – Θ	DIRECTIONS Z – Z	
5	6 7 8 9 10 11 12	13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32	33 34 35 36 37 38 39 40 41 42	
	1	0.500	0.0	0.0	(/)
	2	0.600	0.0	0.0	(/)
	3	0.700	0.0	0.0	(/)
	4	0.800	0.0	0.0	(/)
	5	0.900	0.0	0.0	(/)
	6	1.000	0.0	0.0	(/)
	7	1.000	0.0	0.10	(/)
	8	0.900	0.0	0.10	(/)
	9	0.800	0.0	0.10	(/)
	10	0.700	0.0	0.10	(/)
	11	0.600	0.0	0.10	(/)
	12	0.500	0.0	0.10	(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)

Figure III-J.5 Gridpoint Coordinates, Thick Walled Disk

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

GRID POINT TEMPERATURES

1	2	3	4	5	6	
T	E	M	P			(/)

1	2	3	4	5	6	
M	O	D	A	L		

TEMPERATURES			
T_1	T_2	T_3	
13 – 22	23 – 32	33 – 42	
			(/)

Grid Point Number (3–11)	Repeat (12)	T_1 (13–22)	T_2 (23–32)	T_3 (33–42)	
1		825.00			(/)
12	X				(/)
2		704.00			(/)
11	X				(/)
3		561.00			(/)
10	X				(/)
4		396.00			(/)
9	X				(/)
5		209.00			(/)
8	X				(/)
6		0.00			(/)
7	X				(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)
					(/)

Figure III-J.6 Gridpoint Temperatures, Thick Walled Disk

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE -	0 - No Displacement Allowed 1 - Unknown Displacement 2 - Known Displacement

1	2	3	4	5	6	
B	O	U	N	D		(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	θx	θy	θz	1	2	3	
13	14	15	16	17	18	19	20	21	
1	0	1							(/)

LISTED INPUT

Grid Point Number					Repeat										
7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
			1	2		1	0	0							(/)
															(/)
															(/)
															(/)
															(/)
															(/)
															(/)
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															(/)
															(/)

Figure III-J.7 Boundary Conditions, Thick Walled Disk

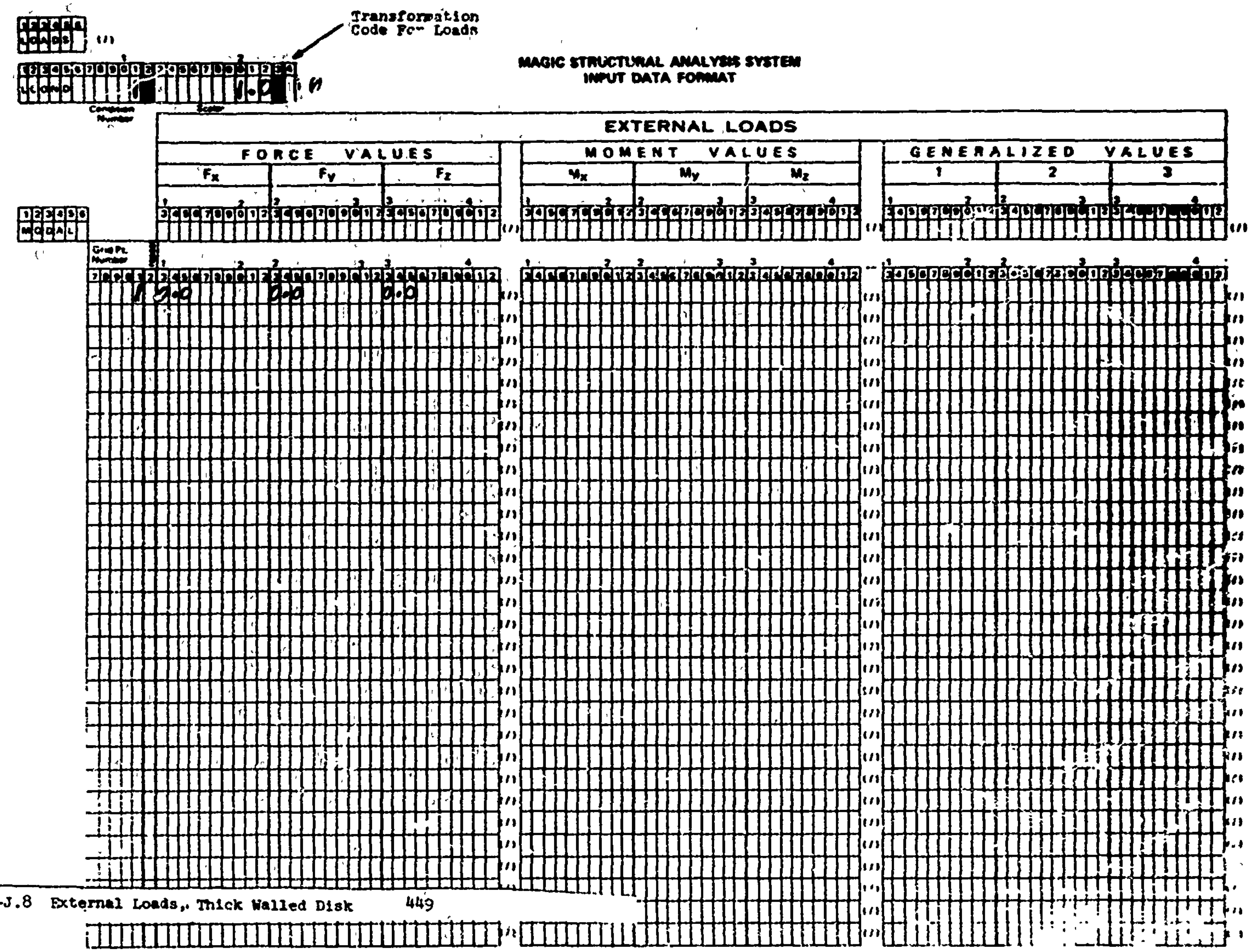


Figure III-J.8 External Loads, Thick Walled Disk

BAC 1628

ELEM 1 2 3 4 5 6	(/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER (7-10)	PLUG NO. (11-12)	MATERIAL NUMBER (13-18)	Interpolate Option (19)	MATERIAL TEMPERATURE (20-27)	Repeat Elem. Matrices (28)	Elim. Input (29)	PRINT: Print (30)	PRINT: Elem. Mat. (31)	PRINT: Full (32)	Number of Input Nodes (33-34)	Suppress Pressures (35)	NODE POINTS 1 (36-38)	2 (39-41)	3 (42-44)	4 (45-47)	5 (48-50)	6 (51-53)	7 (54-56)	8 (57-59)	9 (60-62)	10 (63-65)	11 (66-68)	12 (69-71)	
1	41	12	4						X	4		1	2	11	12									(/)
2	41	12	4							4		2	3	10	11									(/)
3	41	12	4							4		3	4	9	10									(/)
4	41	12	4							4		4	5	8	9									(/)
5	41	12	4							4		5	6	7	8									(/)

Figure III-J.9 Element Control Data, Thick Walled Disk

IF ELEMENT CONTROL DATA MUST BE CONTINUED ON SECOND SHEET, USER MUST DELETE ELEM LABEL CARD FROM SECOND SHEET.

Page ______ of ______

MAGIC STRUCTURAL ANALYSIS SYSTEM

INPUT DATA FORMAT

CHECK OR END CARD

C	H	E	C	K	(/)
1	2	3	4	5	

E	N	D	(/)
1	2	3	

Figure III-J.10 End Card, Thick Walled Disk

The Element Applied Load Scalar was set equal to 1.0 because of the following:

Total Load = External Load + EALS (Element Applied Load)

Since the External Loads are equal to zero and the EALS = 1.0

Total Load = Element Applied Load

These are the correct loads since for this case the Element Applied Loads are equal to the thermal loads.

In Figure III-J.9 (Element Control Data Section) it is important to note a number of items.

(1) The temperature interpolate option (Col. 19) is employed for all five elements. The '4' entered in this location tells the system to average the four node point temperature for each element and use this average temperature when establishing material properties from the material tape.

(2) The node point numbering sequence for each element is very important. Note that each element must be numbered in a counter-clockwise manner when looking in the positive element Y (Θ) direction (Figure III-J.1).

Note also that element numbering always begins at the lower left hand corner of the element. Element Input is not required for this problem.

The output supplied by the MAGIC II System for this application is as follows:

Figures III-J.11 thru III-J.14 display the output from the Structural Systems Monitor. These figures display the input data pertinent to the particular problem being solved.

Figure III-J.12 displays the coordinate information for this application, along with corresponding grid point temperature values.

Figure III-J.13 displays the Boundary Condition and Finite Element Description Output. Note that for this particular application there are twenty-three degrees-of-freedom remaining in the reduced displacement vector (Total Number of Ones).

Figure III-J.14 displays the Transformed External Assembled Load Column. Note that these loads are all equal to zero since this is a thermal stress problem and thermal loads are element applied loads.

MAGIC System output of final results is presented in Figures III-J.15 thru III-J.22.

Figure III-J.15 displays the assembled and reduced stiffness matrix (MATRIX STIFF) of order 23x23. The stiffness matrix is presented row-wise and only non-zero terms are displayed.

The thermal load vector (GPRINT OF MATRIX FTELA) is displayed in Figure III-J.16. These forces are generated at the element level and are output with respect to node point number.

The displacements of the thick walled disk which result from the imposed temperature distribution are shown in Figure III-J.17. It is noted that displacements (U, V, W) are output corresponding to node point number and are referenced to the global axis unless otherwise specified.

Figure III-J.18 displays the reactions. The reactions are listed according to node point number. For this particular application, the reactions are effectively equal to zero which results from the self-equilibrating nature of the thermal loading which is imposed.

Stresses for selected Trapezoidal Ring Elements are presented in Figures III-J.19 and III-J.20. Stresses for Element No. 1 are presented in III-J.19 and stresses for Element No. 5 are presented in Figure III-J.20.

Stresses are evaluated at the four corner points of each element and at the element centroid. In Figure III-J.19, Stress Points 1, 2, 3, and 4 correspond to Element Grid Points 1, 2, 11, and 12 respectively. Stress point 5 corresponds to the element centroidal stress.

The stresses for each element are defined as follows:

$$\{\sigma\} = [E]\{\epsilon\} - \{SZAEL\}$$

where from Figures III-J.19 and III-J.20:

$[E]\{\epsilon\}$ = Apparent Element Stress

$\{SZAEL\}$ = Element Applied Stress

$\{\sigma\}$ = Net Element Stress

Note that Radial, Circumferential, Axial and Shear Stresses are presented for each element.

Element forces for selected Trapezoidal Ring Elements are presented in Figures III-J.21 and III-J.22. Forces for Element No. 1 are presented in III-J.21 and forces for Element No. 5 are presented in III-J.22. These forces are defined with respect to the Global Coordinate System. Each Trapezoidal Ring Element has three element forces defined per grid point (F_R, F_θ, F_Z).

For Element No. 1 (Figure III-J.21) Force Points 1, 2, 3, and 4 correspond to Element Grid Points 1, 2, 11, and 12 respectively. Forces for Element No. 5 (Figure III-J.22) are defined in an analogous manner.

TRAPEZOIDAL RING PROBLEM -BELL IMPLEMENTED FORMAT

THICK WALLED DISK UNDER THERMAL LOADING PLANE STRESS FORMULATION

REFERENCE WANG APPLIED ELASTICITY PAGE 70

S. JORDAN 10 OCTOBER 1967

12 REF. POINTS

NO. DIRECTIONS = 3 NO. DEGREES OF FREEDOM = 1

GRIDPOINT DATA
(IN RECTANGULAR COORDINATES)

POINT	X	Y	Z	TEMPERATURES	PRESSURES
1	0.50000000E 00	0.0	0.0	0.82500000E 03	0.0
				0.0	0.0
				0.0	0.0
2	0.59999996E 00	0.0	0.0	0.70400000E 03	0.0
				0.0	0.0
				0.0	0.0
3	0.69999999E 00	0.0	0.0	0.56100000E 03	0.0
				0.0	0.0
				0.0	0.0
4	0.79999999E 00	0.0	0.0	0.39600000E 03	0.0
				0.0	0.0
				0.0	0.0
5	0.89999999E 00	0.0	0.0	0.20900000E 03	0.0
				0.0	0.0
				0.0	0.0
6	0.10000000E 01	0.0	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
7	0.10000000E 01	0.0	0.99999964E-01	0.0	0.0
				0.0	0.0
				0.0	0.0
8	0.89999998E 00	0.0	0.99999964E-01	0.20900000E 03	0.0
				0.0	0.0
				0.0	0.0
9	0.79999995E 00	0.0	0.99999964E-01	0.39600000E 03	0.0
				0.0	0.0
				0.0	0.0
10	0.69999999E 00	0.0	0.99999964E-01	0.56100000E 03	0.0
				0.0	0.0
				0.0	0.0
11	0.59999996E 00	0.0	0.99999964E-01	0.70400000E 03	0.0
				0.0	0.0
				0.0	0.0
12	0.50000000E 00	0.0	0.99999964E-01	0.82500000E 03	0.0
				0.0	0.0
				0.0	0.0

FIGURE III-J.11 TITLE AND GRIDPOINT DATA OUTPUT, THICK WALLED DISK

```
                         REVISIONS OF MATERIAL TAPE

                   ASTERISK (*) PRECEEDING MATERIAL
                   IDENTIFICATION INDICATES THAT INPUT
                   ERROR RETURNS WILL NOT RESULT IN
                        TERMINATION OF EXECUTION

*****************************************************************************************

  REVISION
    MATERIAL NUMBER      12
    MATERIAL IDENTIFICATION  MATL.FOR BIF TEST              INPUT CODE   1
      NUMBER OF MATERIAL PROPERTY POINTS. . . .  2
      NUMBER OF PLASTIC PROPERTY POINTS . . . .  0
      MASS DENSITY. . . . . . . . . . . . . . .  0.0

    MATERIAL PROPERTIES

                 YOUNG'S MODULI                               POISSON'S RATIOS

                        DIRECTIONS                                          DIRECTIONS
 TEMPERATURE
                 XX              YY              ZZ              XY              YZ              ZX
     0.0     0.180000E 08    0.180000E 08    0.180000E 08    0.300000E 00    0.300000E 00    0.300000E 00
  1500.00    0.180000E 08    0.180000E 08    0.180000E 08    0.300000E 00    0.300000E 00    0.300000E 00

                 TH. EXP.COEF.                                RIGIDITY MODULI

                        DIRECTIONS                                          DIRECTIONS
 TEMPERATURE
                 XX              YY              ZZ              XY              YZ              ZX
     0.0     0.100000E-06    0.100000E-06    0.100000E-06    0.692308E 07    0.692308E 07    0.692308E 07
  1500.00    0.100000E-06    0.100000E-06    0.100000E-06    0.692308E 07    0.692308E 07    0.692308E 07

*****************************************************************************************
```

FIGURE III-J.12 MATERIAL DATA OUTPUT, THICK WALLED DISK

BOUNDARY CONDITION INFORMATION

NODES	DEGREES OF FREEDOM			[illegible]	
1	1	0	1	2	0
2	1	0	1	4	0
3	1	0	1	6	0
4	1	0	1	8	0
5	1	0	1	10	0
6	1	0	1	12	0
7	1	0	1	14	0
8	1	0	1	16	0
9	1	0	1	18	0
10	1	0	1	20	0
11	1	0	1	22	0
12	1	0	0	[illegible]	0

TOTAL NO. ELEMENTS = 5

ELEM	TYPE	MAT.NO.	CODE	TEMP.	PRNT	NO.	GRID POINTS				EXTRA GRID PTS	SECTION PROPERTIES
1	41	12	4	0.0	2	4	1	2	11	12		

MATERIAL NUMBER. 12
MATERIAL IDENTIFICATION. . . . MATL.FOR BIF TEST
ANALYSIS CAPABILITY. . . . . . ISOTROPIC
INPUT PRINT CODE 1
ELEMENT PRINT CODE . . . . -1

INTERPOLATED MATERIAL PROPERTIES

TEMPERATURE -	0.76450000E 03		
YOUNG'S MODULI	0.18000000E 08	0.18000000E 08	0.18000000E 08
POISSON'S RATIO	0.29999995E 00	0.29999995E 00	0.29999995E 00
TH. EXP. COEF.	0.99999966E-07	0.99999966E-07	0.99999966E-07
RIGIDITY MODULI	0.69230800E 07	0.69230800E 07	0.69230800E 07

INTERPOLATED PLASTIC PROPERTIES
NONE

PRE-STRAIN INPUT
NONE

PRE-STRESS INPUT
NONE

EXTERNAL INPUT
NONE

ELEM	TYPE	MAT.NO.	CODE	TEMP.	PRNT	NO.	GRID POINTS				EXTRA GRID PTS	SECTION PROPERTIES		
2	41	12	4	0.6325E 03	0	4	2	3	10	11		0.0	0.0	0.0
3	41	12	4	0.4785E 03	0	4	3	4	9	10		0.0	0.0	0.0
4	41	12	4	0.3025E 03	0	4	4	5	8	9		0.0	0.0	0.0
5	41	12	4	0.1045E 03	0	4	5	6	7	8		0.0	0.0	0.0

FIGURE III-J.13 BOUNDARY CONDITION AND FINITE ELEMENT DESCRIPTION OUTPUT, THICK WALLED DISK

EXTERNAL LOAD CONDITIONS 1

LOAD NO. 1

NUMBER OF LOADED NODES 1 ELEMENT LOAD SCALAR = 0.10000000E 01

1 0.0 0.0 0.0

TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN

36 X 1

0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0

T-ZERO FOR STRUCTURE = 0.0

FIGURE III-J.14 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, THICK WALLED DISK

MATRIX STIFF

CUTOFF = 0.0 SIZE 23 BY 23

		FORCE		FORCE		FORCE		FORCE		FORCE	
DISP	1	1	-0.775773E 09	2	0.134121E 08	3	0.785674E 09	4	0.289996E 07	21	-0.827311E 09
		22	-0.144597E 08	23	0.814062E 09						
DISP	2	1	0.134121E 08	2	-0.252729E 10	3	-0.308113E 07	4	0.256789E 10	21	-0.154059E 08
		22	-0.257985E 10	23	0.181245E 07						
DISP	3	1	0.785674E 09	2	-0.308113E 07	3	-0.202649E 10	4	-0.362615E 06	5	0.126776E 10
		6	0.344373E 07	19	-0.131705E 10	20	-0.172183E 08	21	0.211869E 10	22	0.181247E 07
		23	-0.827311E 09								
DISP	4	1	0.289996E 07	2	0.256789E 10	3	-0.362615E 06	4	-0.669884E 10	5	-0.362483E 07
		6	0.422230E 10	19	-0.181245E 08	20	-0.423644E 10	21	-0.181248E 07	22	0.672494E 10
		23	0.144597E 08								
DISP	5	3	0.126776E 10	4	-0.362483E 07	5	-0.315609E 10	6	-0.362720E 06	7	0.191951E 10
		8	0.398750E 07	17	-0.197643E 10	18	-0.199370E 08	19	0.326339E 10	20	0.181250E 07
		21	-0.131705E 10	22	0.181245E 08						
DISP	6	3	0.344373E 07	4	0.422230E 10	5	-0.362720E 06	6	-0.105862E 11	7	-0.416844E 07
		8	0.647048E 10	17	-0.208432E 08	18	-0.648679E 10	19	-0.181249E 07	20	0.106167E 11
		21	0.172183E 08	22	-0.423644E 10						
DISP	7	5	0.191951E 10	6	-0.416844E 07	7	-0.465107E 10	8	-0.362832E 06	9	0.276700E 10
		10	0.453129E 07	15	-0.283155E 10	16	-0.226557E 08	17	0.477356E 10	18	0.181253E 07
		19	-0.197643E 10	20	0.208432E 08						
DISP	8	5	0.398750E 07	6	0.647048E 10	7	-0.362832E 06	8	-0.157524E 11	9	-0.471220E 07
		10	0.940376E 10	15	-0.235619E 08	16	-0.942224E 10	17	-0.181253E 07	18	0.157672E 11
		19	0.199371E 08	20	-0.648679E 10						
DISP	9	7	0.276700E 10	8	-0.471220E 07	9	-0.656362E 10	10	-0.362640E 06	11	0.383634E 10
		12	0.507499E 07	13	-0.390852E 10	14	-0.253745E 08	15	0.670121E 10	16	0.181249E 07
		17	-0.283155E 10	18	0.235619E 08						
DISP	10	7	0.453129E 07	8	0.940376E 10	9	-0.362640E 06	10	-0.223802E 11	11	-0.525604E 07
		12	0.131135E 11	13	-0.262807E 08	14	-0.131342E 11	15	-0.181250E 07	16	0.224194E 11
		17	0.226557E 08	18	-0.942224E 10						
DISP	11	9	0.383634E 10	10	-0.525604E 07	11	-0.381288E 10	12	-0.273683E 08	13	0.388872E 10
		14	0.634364E 07	15	-0.390852E 10	16	0.262807E 08				
DISP	12	9	0.507499E 07	10	0.131135E 11	11	-0.273683E 08	12	-0.130399E 11	13	-0.634365E 07
		14	0.130606E 11	15	0.253745E 08	16	-0.131342E 11				
DISP	13	9	-0.390852E 10	10	-0.262807E 08	11	0.388872E 10	12	-0.634365E 07	13	-0.381288E 10
		14	0.273683E 08	15	0.383634E 10	16	0.525604E 07				

FIGURE III-J.15 REDUCED STIFFNESS MATRIX OUTPUT. THICK WALLED DISK

CUTOFF = 0.0 SIZE 23 BY 23

		FORCE		FORCE		FCRCE		FORCE		FORCE	
DISP	14	9	-0.253745E 08	10	-0.131342E 11	11	0.634364E 07	12	0.130606E 11	13	0.273683E 08
		14	-0.130399E 11	15	-0.507499E 07	16	0.131135E 11				
DISP	15	7	-0.283155E 10	8	-0.235619E 08	9	0.670121E 10	10	-0.181250E 07	11	-0.390852E 10
		12	0.253745E 08	13	0.383634E 10	14	-0.507499E 07	15	-0.656362E 10	16	0.362656E 06
		17	0.276700E 10	18	0.471221E 07						
DISP	16	7	-0.226557E 08	8	-0.942224E 10	9	0.181249E 07	10	0.224194E 11	11	0.262807E 08
		12	-0.131342E 11	13	0.525604E 07	14	0.131135E 11	15	0.362656E 06	16	-0.223802E 11
		17	-0.453130E 07	18	0.940376E 10						
DISP	17	5	-0.197643E 10	6	-0.208432E 08	7	0.477350E 10	8	-0.181253E 07	9	-0.283155E 10
		10	0.226557E 08	15	0.276700E 10	16	-0.453130E 07	17	-0.465107E 10	18	0.362848E 06
		19	0.191951E 10	20	0.416845E 07						
DISP	18	5	-0.199370E 08	6	-0.648679E 10	7	0.181253E 07	8	0.157872E 11	9	0.235619E 08
		10	-0.942224E 10	15	0.471221E 07	16	0.940376E 10	17	0.362848E 06	18	-0.157524E 11
		19	-0.398759E 07	20	0.647048E 10						
DISP	19	3	-0.131705E 10	4	-0.181245E 08	5	0.326339E 10	6	-0.181249E 07	7	-0.197643E 10
		8	0.199371E 08	17	0.191951E 10	18	-0.398759E 07	19	-0.315609E 10	20	0.362704E 06
		21	0.126776E 10	22	0.362483E 07						
DISP	20	3	-0.172183E 08	4	-0.423644E 10	5	0.181250E 07	6	0.106167E 11	7	0.208432E 08
		8	-0.648679E 10	17	0.416845E 07	18	0.647048E 10	19	0.362704E 06	20	-0.105862E 11
		21	-0.344373E 07	22	0.422230E 10						
DISP	21	1	-0.827311E 09	2	-0.154059E 08	3	0.211869E 10	4	-0.181248E 07	5	-0.131705E 10
		6	0.172183E 08	19	0.126776E 10	20	-0.344373E 07	21	-0.202649E 10	22	0.362616E 06
		23	0.785674E 09								
DISP	22	1	-0.144997E 08	2	-0.257985E 10	3	0.181247E 07	4	0.672494E 10	5	0.181245E 08
		6	-0.423644E 10	19	0.362483E 07	20	0.422230E 10	21	0.362616E 06	22	-0.669884E 10
		23	-0.289996E 07								
DISP	23	1	0.814862E 09	2	0.181245E 07	3	-0.827311E 09	4	0.144997E 08	21	0.785674E 09
		22	-0.289996E 07	23	-0.775773E 09						

FIGURE III-J.15 REDUCED STIFFNESS MATRIX OUTPUT, THICK WALLED DISK (CONTINUED)

GPRINT OF MATRIX FTELA (SET 1)

ROW	FX	FY	FZ
1	-0.53753735E 03	0.0	0.51483906E 04
2	0.11248315E 03	0.0	0.42485000E 04
3	0.15291504E 03	0.0	0.75037930E 04
4	0.19956128E 03	0.0	0.11934789E 05
5	0.25245166E 03	0.0	0.17709328E 05
6	0.14280440E 03	0.0	-0.50899023E 05
7	0.14281168E 03	0.0	0.50899023E 05
8	0.25243875E 03	0.0	-0.17709328E 05
9	0.19957178E 03	0.0	-0.11934789E 05
10	0.15291235E 03	0.0	-0.75037930E 04
11	0.11248462E 03	0.0	-0.42485000E 04
12	-0.53753955E 03	0.0	-0.51483906E 04

FIGURE III-J.16 ELEMENT APPLIED LOADS OUTPUT, THICK WALLED DISK

DISPLACEMENT MATRIX FOR LOAD CONDITION 1

36 X 1

ROW	U	V	W
1	0.22651118E-04	0.0	-0.11880407E-04
2	0.30104522E-04	0.0	-0.71769900E-05
3	0.35842037E-04	0.0	-0.22633176E-05
4	0.39443392E-04	0.0	0.28473441E-05
5	0.42367392E-04	0.0	0.81525359E-05
6	0.43018634E-04	0.0	0.13646294E-04
7	0.39476363E-04	0.0	0.10080157E-04
8	0.38825718E-04	0.0	0.84730273E-05
9	0.36402431E-04	0.0	0.66632929E-05
10	0.32302196E-04	0.0	0.46531350E-05
11	0.26566006E-04	0.0	0.24356414E-05
12	0.19115134E-04	0.0	0.0

FIGURE III-J.17 DISPLACEMENT OUTPUT, THICK WALLED DISK

REACTIONS ANC INVERSE CHECK FOR LOAD CONDITION

ROW	FX	FY	FZ
1	0.14672852E 00	0.0	-0.58593750E-01
2	-0.33081055E CO	0.0	0.25781250E 00
3	0.5C711060E 00	0.0	-0.41796875E 00
4	-0.23529053E 00	0.0	0.46875000E 00
5	0.36048889E 00	0.0	0.39062500E 00
6	-0.43965149E 00	0.0	-0.29296875F 00
7	0.34791565E 00	0.0	0.62500000E 00
8	-0.35240173E 00	0.0	-0.19140625E 00
9	0.17224121E 00	0.0	-0.38281250E 00
10	-0.53671265E 00	0.0	0.48828125E 00
11	0.33178711E 00	0.0	-0.22656250E 00
12	-0.15966797E 00	0.0	-0.71875000E 00

FIGURE III-J.18 REACTION OUTPUT, THICK WALLED DISK

S T R E S S E S F O R T H E T R A P E Z O I D A L R I N G E L E M E N T

(STRESS POINT FIVE EQUALS ELEMENT STRESSES EVALUATED AT ELEMENT CENTROID)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	41	1 2 11 12

APPARENT ELEMENT STRESSES

STRESS POINT	RADIAL (SIGMA-R)	CIRCUMFERENTIAL (SIGMA-THETA)	AXIAL (SIGMA-Z)	SHEAR (SIGMA-RZ)
1	0.35101985E 04	0.31054487E 04	0.41231641E 04	0.80822754E 02
2	0.33252903E 04	0.29879995E 04	0.36242603E 04	0.80647217E 02
3	0.32634297E 04	0.28440333E 04	0.35627500E 04	-0.76352605E 02
4	0.34361406E 04	0.29338271E 04	0.40494609E 04	-0.76177002E 02
5	0.33863391E 04	0.29740415E 04	0.38424844E 04	0.22351074E 01

ELEMENT APPLIED STRESSES

STRESS POINT	RADIAL (SIGMA-R)	CIRCUMFERENTIAL (SIGMA-THETA)	AXIAL (SIGMA-Z)	SHEAR (SIGMA-RZ)
1	0.37124976E 04	0.37124976E 04	0.37124976E 04	0.0
2	0.31679978E 04	0.31679978E 04	0.31679978E 04	0.0
3	0.31679978E 04	0.31679978E 04	0.31679978E 04	0.0
4	0.37124976E 04	0.37124976E 04	0.37124976E 04	0.0
5	0.34402478E 04	0.34402478E 04	0.34402478E 04	0.0

NET ELEMENT STRESSES

STRESS POINT	RADIAL (SIGMA-R)	CIRCUMFERENTIAL (SIGMA-THETA)	AXIAL (SIGMA-Z)	SHEAR (SIGMA-RZ)
1	-0.20229907E 03	-0.60704883E 03	0.41066650E 03	0.80822754E 02
2	0.15729248E 03	-0.17999829E 03	0.45626245E 03	0.80647217E 02
3	0.95431885E 02	-0.32316455E 03	0.39475220E 03	-0.76352600E 02
4	-0.27635693E 03	-0.77867041E 03	0.33696338E 03	-0.76177002E 02
5	-0.53908691E 02	-0.46620630E 03	0.40223657E 03	0.22351074E 01

FIGURE III-J.19 STRESS OUTPUT, ELEMENT NO. 1, THICK WALLED DISK

STRESSES FOR THE TRAPEZOIDAL RING ELEMENT

(STRESS POINT FIVE EQUALS ELEMENT STRESSES EVALUATED AT ELEMENT CENTROID)

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	5	41	5 6 7 8

APPARENT ELEMENT STRESSES

STRESS POINT	RADIAL (SIGMA-R)	CIRCUMFERENTIAL (SIGMA-THETA)	AXIAL (SIGMA-Z)	SHEAR (SIGMA-RZ)
1	0.67993677E 03	0.12415693E 04	0.63413989E 03	0.13514331E 03
2	0.23420410E 03	0.73967285E 03	-0.34974707E 03	0.13510181E 03
3	0.15726563E 03	0.65377612E 03	-0.38659302E 03	-0.13397217E 03
4	0.63892651E 03	0.11461545E 04	0.59320776E 03	-0.13393066E 03
5	0.43652759E 03	0.94283496E 03	0.12169897E 03	0.58496094E 00

ELEMENT APPLIED STRESSES

STRESS POINT	RADIAL (SIGMA-R)	CIRCUMFERENTIAL (SIGMA-THETA)	AXIAL (SIGMA-Z)	SHEAR (SIGMA-RZ)
1	0.94049927E 03	0.94049927E 03	0.94049927E 03	0.0
2	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0
4	0.94049927E 03	0.94049927E 03	0.94049927E 03	0.0
5	0.47024951E 03	0.47024951E 03	0.47024951E 03	0.0

NET ELEMENT STRESSES

STRESS POINT	RADIAL (SIGMA-R)	CIRCUMFERENTIAL (SIGMA-THETA)	AXIAL (SIGMA-Z)	SHEAR (SIGMA-RZ)
1	-0.26056250E 03	0.30107007E 03	-0.30635938E 03	0.13514331E 03
2	0.23420410E 03	0.73967285E 03	-0.34974707E 03	0.13510181E 03
3	0.15726563E 03	0.65377612E 03	-0.38659302E 03	-0.13397217E 03
4	-0.30157275E 03	0.20565527E 03	-0.34729150E 03	-0.13393066E 03
5	-0.33721924E 02	0.47258545E 03	-0.34855054E 03	0.58496094E 00

FIGURE III-J.20 STRESS OUTPUT, ELEMENT NO. 5, THICK WALLED DISK

FORCES FOR THE TRAPEZOIDAL [illegible]

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	1	41	1 2 11 12

APPARENT ELEMENT FORCES

POINT	RADIAL (FR)	CIRCUMFERENTIAL (F-THETA)	AXIAL (FZ)
1	-0.53739063E 03	0.0	0.51483320E 04
2	0.43081250E 03	0.0	-0.64733438E 04
3	0.43102344E 03	0.0	0.64741133E 04
4	-0.53769922E 03	0.0	-0.51491094E 04

ELEMENT APPLIED FORCES

POINT	RADIAL (FR)	CIRCUMFERENTIAL (F-THETA)	AXIAL (FZ)
1	-0.53753723E 03	0.0	0.51483906E 04
2	0.64561548E 03	0.0	-0.63343984E 04
3	0.64561743E 03	0.0	0.63343984E 04
4	-0.53753955E 03	0.0	-0.51483906E 04

NET ELEMENT FORCES

POINT	RADIAL (FR)	CIRCUMFERENTIAL (F-THETA)	AXIAL (FZ)
1	0.14672852E 00	0.0	-0.58593750E-01
2	-0.14802979E 02	0.0	-0.13894531E 03
3	-0.14593994E 02	0.0	0.13971484E 03
4	-0.15966797E 00	0.0	-0.71875000E 00

FIGURE III-J.21 FORCE OUTPUT, ELEMENT NO. 1, THICK WALLED DISK

FORCES FOR THE TRAPEZOIDAL RING ELEMENT

LOAD CONDITION NUMBER	ELEMENT NUMBER	ELEMENT TYPE	ELEMENT GRID POINTS
1	5	4	5 6 7 8

APPARENT ELEMENT FORCES

POINT	RADIAL (FR)	CIRCUMFERENTIAL (F-THETA)	AXIAL (FZ)
1	-0.11255779E 03	0.0	0.50931504E 05
2	0.14236475E 03	0.0	-0.50899316E 05
3	0.14315559E 03	0.0	0.50899648E 05
4	-0.11359630E 03	0.0	-0.50931961E 05

ELEMENT APPLIED FORCES

POINT	RADIAL (FR)	CIRCUMFERENTIAL (F-THETA)	AXIAL (FZ)
1	-0.12803101E 03	0.0	0.50623250E 05
2	0.14280440E 03	0.0	-0.50899023E 05
3	0.14281169E 03	0.0	0.50899023E 05
4	-0.12803830E 03	0.0	-0.50623250E 05

NET ELEMENT FORCES

POINT	RADIAL (FR)	CIRCUMFERENTIAL (F-THETA)	AXIAL (FZ)
1	0.15433212E 02	0.0	0.20825391E 03
2	-0.43965149E 00	0.0	-0.29296875E 00
3	0.34791565E 00	0.0	0.62500000E 00
4	0.14442001E 02	0.0	-0.20871094E 03

$END

FIGURE III-J.22 FORCE OUTPUT, ELEMENT NO. 5, THICK WALLED DISK

K. SQUARE PLATE - CRITICAL BUCKLING LOAD (Quadrilateral Plate Idealization)

A simply supported square plate, under the action of uniform axial compressive loading is shown in Figure III-K.1 along with its dimensions and pertinent material properties. A linear eigenvalue stability analysis is performed in this analysis. One quadrant of the plate is analyzed (using 16 elements) and an alternate analytical solution is provided in Reference 17.

The preprinted input data forms associated with this application are displayed in Figures III-K.2 thru III-K.11.

In Figure III-K.6 (Boundary Condition Section) it is instructive to note the use of the MODAL and Repeat options. There are 16 exceptions to the MODAL card as seen from the Figure.

In Figure III-K.7, DYNAM Section, note that two eigenvalues are requested. These two eigenvalues correspond to the first and second buckling modes respectively.

In Figure III-K.10 (Element Input) it is noted that only the MODAL entry is used. This means that all the quadrilateral plate elements used in this analysis have identical element input as follows:

Location A - Membrane Thickness (t_m) = 0.10 in.

Location B - Flexure Thickness (t_f) = 0.10 in.

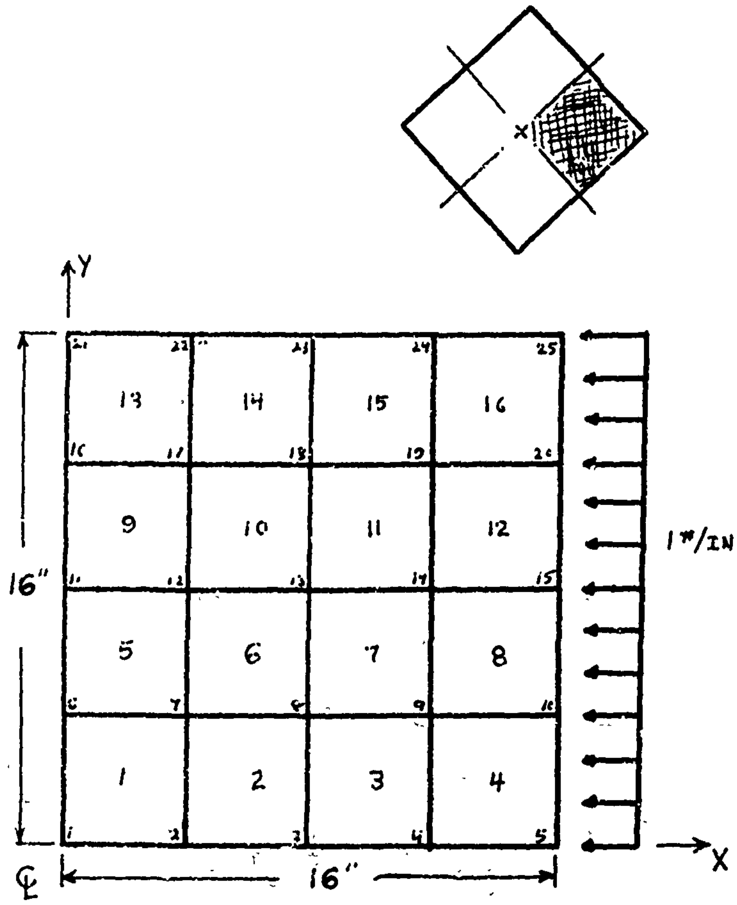
The output supplied by the MAGIC System for this analysis is as follows:

Figure III-K.12 shows the matrix abstraction instructions associated with this particular problem. Note that the STABILITY Agendum was utilized. A full discussion of these instructions is presented on pages 69 thru 80 of this report.

Figures III-K.13 thru III-K.17 display selected output from the Structural Systems Monitor. These figures record the input data pertinent to the problem being solved.

Selected MAGIC System output of final results is displayed in Figures III-K.18 thru III-K.22.

The Externally Applied Load Vector (GPRINT OF MATRIX LOADS) is presented in Figure III-K.18. From the figure it is observed that Grid Points 5, 10, 15, 20 and 25 are loaded in the negative Global 'X' direction.



$E = 30 \times 10^6$ psi

$t = 0.10$ in

$\nu = 0.30$

$$(N_x)_{CR} = \frac{4 \; {}^{2}D}{b^2} \quad \text{(Reference 17)}$$

FIGURE III-K.1 IDEALIZED SIMPLY SUPPORTED PLATE, CRITICAL BUCKLING LOAD

BAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

REPORT (/)

1 2 3 4 5 6

TITLE (/)

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

7 8 9

2 (/) NUMBER OF TITLE CARDS

SIMPLY SUPPORTED SQUARE PLATE- MAGIC II TEST 5-29- (/)

CRITICAL BUCKLING LOAD- ONE QUARTER ANALYZED (/)

Figure III-K.2 Title Information, Critical Buckling Load

BAC 1616-1

MATER (/)
1 2 3 4 5 6

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1 (/)
7 8 9
No. of Requests

MATERIAL TAPE INPUT

Request Number (7-9)	MATERIAL NUMBER (10-15)	Lock Code (16-17)	MATERIAL IDENTIFICATION (18-41)	Isotropic (42)	Orthotropic (43)	Plastic Isotropic (44)	Plastic Orthotropic (45)	Add Plastic (46)	Delete Material (47)	Print Tape (48)	Print Mat'l. Table (49)	Print Mat'l. Summary (50)	Number of Mat'l. Pts. (51-52)	Number of Plastic Pts. (53-54)	MASS DENSITY (55-64)	
1	1	SJ	XXXXXXXXXXXXXXXXXXXXXXXX	X									1		0.0	(/)

MATERIAL PROPERTIES TABLE

TEMPERATURE (13-22)	Direction	YOUNGS MODULI (23-32)	Direction	POISSONS RATIOS (33-42)	Direction	COEF. OF THERMAL EXPANSION (43-52)	Direction	RIGIDITY MODULI (53-62)	
0.0	E_x	0.30 E8	ν_{xy}	0.30	α_x		G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

Figure III-K.3 Material Tape Input, Critical Buckling Load

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

> ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

	S Y S T E M (/)	1 2 3 4 5 6
1. Number of System Grid Points	25	1 2 3 4 5 6
2. Number of Input Grid Points	25	7 8 9 10 11 12
3. Number of Degrees of Freedom/Grid Point	6	13 14
4. Number of Load Conditions	1	15 16
5. Number of Initially Displaced Grid Points		17 18 19 20 21 22
6. Number of Prescribed Displaced Grid Points		23 24 25 26 27 28
7. Number of Grid Point Axes Transformation Systems		29 30
8. Number of Elements	16	31 32 33 34 35 36
9. Number of Requests and/or Revisions of Material Tape.	1	37 38
10. Number of Input Boundary Condition Points	16	39 40 41 42 43 44
11. T_0 For Structure (With Decimal Point)	0.0 (/)	45 46 47 48 49 50 51 52

Figure III-K.4 System Control Information, Critical Buckling Load

BAC 1622

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1	2	3	4	5	6
C	O	O	R	D	

(/)

GRIDPOINT COORDINATE

COORD. INPUT	$
RECTANGULAR	R/Δ
CYLINDRICAL	C
SPHERICAL	S

SYSTEM

Δ = BLANK

$	Grid Point Number	X – R	Y – θ	Z – Z	
	1	0.0	0.0	0.0	(/)
	2	4.0	0.0		(/)
	3	8.0	0.0		(/)
	4	12.0	0.0		(/)
	5	16.0	0.0		(/)
	6	0.0	4.0		(/)
	7	4.0	4.0		(/)
	8	8.0	4.0		(/)
	9	12.0	4.0		(/)
	10	16.0	4.0		(/)
	11	0.0	8.0		(/)
	12	4.0	8.0		(/)
	13	8.0	8.0		(/)
	14	12.0	8.0		(/)
	15	16.0	8.0		(/)
	16	0.0	12.0		(/)
	17	4.0	12.0		(/)
	18	8.0	12.0		(/)
	19	12.0	12.0		(/)
	20	16.0	12.0		(/)
	21	0.0	16.0		(/)
	22	4.0	16.0		(/)
	23	8.0	16.0		(/)
	24	12.0	16.0		(/)
	25	16.0	16.0	0.0	(/)
					(/)
					(/)
					(/)
					(/)

If coordinate information must be continued on second sheet, user MUST delete Coord. Label Card from second sheet.

Figure III-K.5 Gridpoint Coordinates, Critical Buckling Load

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE -	0 - No Displacement Allowed 1 - Unknown Displacement 2 - Known Displacement

1	2	3	4	5	6	
B	O	U	N	D		(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED			
U	V	W	Θ_x	Θ_y	Θ_z	1	2	3	
13	14	15	16	17	18	19	20	21	
1	1	1	1	1	0				(/)

LISTED INPUT

Grid Point Number (7–11)	Repeat (12)	13	14	15	16	17	18	19	20	21	
1		0	0	1	0	0	0				(/)
2		1	0	1	0	1	0				(/)
3	X										(/)
4	X										(/)
5		1	0	0	0	1	0				(/)
6		0	1	1	1	0	0				(/)
10		1	1	0	0	1	0				(/)
11		0	1	1	1	0	0				(/)
15		1	1	0	0	1	0				(/)
16		0	1	1	1	0	0				(/)
20		1	1	0	0	1	0				(/)
21		0	1	0	1	0	0				(/)
22		1	1	0	1	0	0				(/)
23	X										(/)
24	X										(/)
25		1	1	0	0	0	0				(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)

Figure III-K.6 Boundary Conditions, Critical Buckling Load

DYNAMICS INFORMATION

D	Y	N	A	M		(/)
1	2	3	4	5	6	

		Columns
1.	Number of Eigenvalues Requested (Less than or Equal to 20)	1 2 (2)
2.	Convergence Criteria (Floating Point) (Default Option - 0.001)	3 4 5 6 7 8 9 10 11 12 13 14
3.	Maximum Number of Iterations (Default Option - 500 Iterations)	15 16 17
4.	Debug Iteration Print Iteration Print ON = 1 Iteration Print OFF = 0 (Default Option - Print OFF)	18
5.	First Normalizing Element for Print (Default Option - No First Normalization)	19 20 21 22
6.	Second Normalizing Element for Print (Default Option - No Second Normalization)	23 24 25 26
7.	Control for Guess Vector Iteration Start Column Iteration Start = 0 Row Iteration Start = 1 (Default Option - Column Iteration Start)	27 (/)

Figure III-K.7 Dynamics Information, Critical Buckling Load

BAC 1627

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

LOADS (1)

LCOND | Condition Number: 1 | Scalar: 1.0 | (1)

Transformation Code For Loads

MODAL

EXTERNAL LOADS

Grid Pt. Number	Force Values F_x	Force Values F_y	Force Values F_z	Moment Values M_x	Moment Values M_y	Moment Values M_z	Generalized Values 1	Generalized Values 2	Generalized Values 3
5	-2.0	0.0	0.0	0.0	0.0	0.0			
10	-4.0	0.0	0.0	0.0	0.0	0.0			
15	-4.0	0.0	0.0	0.0	0.0	0.0			
20	-4.0	0.0	0.0	0.0	0.0	0.0			
25	-2.0	0.0	0.0	0.0	0.0	0.0			

Figure XI-K.8 External Loads, Critical Buckling Load

BAC 1676

ELEM (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

Element Number	Plug No.	Material Number	Interpolate Option	Material Temperature	Repeat Elem. Matrices	Elem. Input	Print: Print	Print: Elem. Mat.	Print: Full	Number of Input Nodes	Suppress Pressures	Node 1	Node 2	Node 3	Node 4	Node 5	Node 6	Node 7	Node 8	Node 9	Node 10	Node 11	Node 12
1	28	1				X	X			4		1	2	7	6								
2	28	1				X	X			4		2	3	8	7								
3	28	1				X				4		3	4	9	8								
4	28	1				X				4		4	5	10	9								
5	28	1				X				4		6	7	12	11								
6	28	1				X				4		7	8	13	12								
7	28	1				X				4		8	9	14	13								
8	28	1				X				4		9	10	15	14								
9	28	1				X				4		11	12	17	16								
10	28	1				X				4		12	13	18	17								
11	28	1				X				4		13	14	19	18								
12	28	1				X				4		14	15	20	19								
13	28	1				X				4		16	17	22	21								
14	28	1				X				4		17	18	23	22								
15	28	1				X				4		18	19	24	23								
16	28	1				X	X			4		19	20	25	24								

Figure III-K.9 Element Control Data, Critical Buckling Load

IF ELEMENT CONTROL DATA MUST BE CONTINUED ON SECOND SHEET, USER MUST DELETE ELEM LABEL CARD FROM SECOND SHEET.

BAC 1629-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT INPUT

E	X	T	E	R	N	(/)
1	2	3	4	5	6	

1 2 3 4 5 6	A (13–22)	B (23–32)	C (33–42)	D (43–52)	E (53–62)	F (63–72)
MODAL	0.10	0.10				

Element Number (7–11)	Repeat (12)	A (13–22)	B (23–32)	C (33–42)	D (43–52)	E (53–62)	F (63–72)	
								(/
								(/
								(/
								(/
								(/
								(/
								(/
								(/
								(/
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)

Figure III-K.10 Element Input, Critical Buckling Load

Page ______ of ______

CHECK OR END CARD

C	H	E	C	K	
1	2	3	4	5	(/)

E	N	D	
1	2	3	(/)

Figure III-K.11 End Card, Critical Buckling Load

The displacements resulting from the applied loading are displayed in Figure III-K.19.

It is noted that the displacements (U, V, W, THETAX, THETAY, THETAZ) are output corresponding to node point numbers and are referenced to the global axis unless otherwise specified.

Stresses for selected quadrilateral plate elements are presented in Figures III-K.20 and III-K.21. Stresses for Element No. 1 are presented in Figure III-K.20. Centroidal stresses are output at STRESS POINT 1.

The lowest buckling load and associated node shape is presented in Figure III-K.22.

In Figure III-K.22, the interpretation of the predicted result for Eigenvalue 1 is as follows:

The relation governing the prediction of stability is as follows:

$$[K]^{-1}[N]\{\delta\} = \left(\frac{\bar{P}}{P_{cr}}\right)\{\delta\}$$

$[K]^{-1}$ = Inverse, Assembled and Reduced Stiffness Matrix

$[N]$ = Assembled and Reduced Incremental Matrix

$\bar{P}$ = Applied Load Level

P_{cr} = Critical Buckling Load

Extracting the largest eigenvalue from the above relation yields the lowest buckling load.

For this application

$$\frac{\bar{P}}{P_{cr}} = \text{Eigenvalue 1} = 0.95970668 \text{ E-2}$$

$$\text{Therefore } P_{cr} = \frac{1}{0.95970668 \text{ E-2}} = 104.20 \text{ lb/in.}$$

From Reference 17, the critical buckling load for this application is given as 105.91 lb/in. The error between the finite element solution and the alternate analytical solution is less than two percent for this idealization.

$INSTRUCTION STABILITY

```
        C
        C-----STABILITY AGENDUM ANALYSIS
        C
        C        STABILITY ANALYSIS INSTRUCTION SEQUENCE
        C
        C        GENERATE ELEMENT MATRICES
        C
    1           ,MLIB,INTP,XLD ,TR,  ,KEL,FTEL,SEL,STEL,,,SC,EM,=,,    ,.USER04.
        C
        C        FORM (1 X 1) UNIT AND (1 X 1) NULL MATRICES
        C        DETERMINE PRINT FORMAT FOR TYPE OF ELEMENTS USED
        C
    2           I1 = SC.IDENTC.
    3           I3 = I1.NULL.SC
    4           DIFF = I3.SMULT.SC(10,1)
        C
        C        ASSEMBLE STIFFNESS MATRIX AND ELEMENT APPLIED LOADS
        C
    5           STIFF= EM .ASSEM. SC,(1)
    6           FTELA = EM .ASSEM .SC,(40)
    7           LSCALE,LOADS = XLD .DEJOIN.(1,1)
    8           PRINT(FORCE,DISP,,) STIFF
        C
        C        MULTIPLY ELEMENT APPLIED LOADS BY LOAD SCALAR
    9           FTELS = FTELA.MULT.LSCALE
        C        TRANSFORM EXTERNAL LOADS TO 0-1-2 ASSEMBLED SYSTEM
   10           LOADO = TR.MULT.LOADS
        C        FORM TOTAL LOAD COLUMNS
   11           TLOAD = FTELS.ADD.LOADO
        C        FORM REDUCED TOTAL LOAD COLUMN
   12           TL,TLOADR = TLOAD.DEJOIN.( SC(5,1),1)
        C
        C        PRINT FLEXIBILITY MATRIX
        C
   13           FLEX = STIFF.INVERS.
   14           PRINT (DISP,FORCE,,) FLEX
        C
        C        SOLVE FOR DISPLACEMENTS
        C
   15           XR = FLEX.MULT.TLOADR
   16           TR0,TR12 = TR.DEJOIN.(SC(5,1),1)
   17           X = TR12.TMULT.XR
   18           XO = TR.MULT.X
   19           IF (DIFF.NULL.) GO TO 10
        C
        C        PRINT ELEMENT APPLIED LOADS AND EXTERNAL LOADS
        C
        C        ELEMENTS HAVE 1 OR 2 DEGREES OF FREEDOM
        C
   20           GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,TR )FTELA
```

FIGURE III-K.12 MAGIC ABSTRACTION INSTRUCTION LISTING FOR STABILITY

```
           GPRINT(4,,,FX.FY.FZ.MX.MY.MZ,SC,    )LOADS
           GPRINT(2,,,U.V.W.THETAX.THETAY.THETAZ,SC,   ) X
           IF (I3.NULL.) GO TO 60
C
C             ELEMENTS HAVE 3 DEGREES OF FREEDOM
C
     50    GPRINT(4,,,FR.O.FZ.O.MBETA.O.F1.O.F3,SC,TR )FTELA
           GPRINT(4,,,FR.O.FZ.O.MBETA.O.F1.O.F3,SC,    )LOADS
           GPRINT(2,,,U.O.W.O.THETAY.O.W*.O.W**,SC,   ) X
C
C             GENERATE STRESSES
C
     60    STRESS = EM,XO .STRESS. (4,)
C
C             GENERATE ELEMENT INCREMENTAL STIFFNESS MATRIX
C
           ,,,,,,,,,,NEL,,   ,EL,=,INTF,    ,STRESS.USER04.
C
C             ASSEMBLE AND REDUCE INCREMENTAL MATRIX
C
           INCR = EL .ASSEM. SC,(3)
           PRINT(,,,) INCR
C
C             CREATE INPUT EIGENVALUE MATRIX
C
           EIG = FLEX.MULT.INCR
           PRINT (,,,) EIG
C
C             CALCULATE AND PRINT E-VALUES,E-VECTORS,FREQUENCIES
C
           EVALUE,EVECTR,, = EIG, .EIGEN1. SC
           GPRINT(3,,,,SC,TR12) EVECTR,EVALUE
```

FIGURE III-K.12 MAGIC ABSTRACTION INSTRUCTION LISTING FOR STABILITY (CONTINUED)

```
                         SIMPLY SUPPORTED SQUARE PLATE -MAGIC II T... ...

          S JORDAN       CRITICAL BUCKLING LOAD -ONE QUARTER ANALYZED

                              REVISIONS OF MATERIAL TAPE

                           ASTERISK (*) PRECEEDING MATERIAL
                           IDENTIFICATION INDICATES THAT INPUT
                           ERROR RETURNS WILL NOT RESULT IN
                                TERMINATION OF EXECUTION

******************************************************************************************************

   REVISION                                                          INPUT CODE    I
     MATERIAL NUMBER          1
     MATERIAL IDENTIFICATION XXXXXXXXXXXXXXXXXXXXXXXX
       NUMBER OF MATERIAL PROPERTY POINTS. . . .  1
       NUMBER OF PLASTIC PROPERTY POINTS . . . .  0
       MASS DENSITY. . . . . . . . . . . . . . .  0.0

     MATERIAL PROPERTIES

                   YOUNG'S MODULI                                  POISSON'S RATIOS

                            DIRECTIONS                                               DIRECTIONS

  TEMPERATURE        XX              YY              ZZ              XY              YZ              ZX
     0.0        0.300000E 08    0.300000E 08    0.300000E 08    0.3000CCE 00    0.300000E 00    0.300000E 00

                   TH. EXP.COEF.                                   RIGIDITY MODULI

                            DIRECTIONS                                               DIRECTIONS

  TEMPERATURE        XX              YY              ZZ              XY              YZ              ZX
     0.0        0.0             0.0             0.0             0.115385E 08    0.115385E 08    0.115385E 08

******************************************************************************************************
```

FIGURE III-K.13 TITLE AND MATERIAL DATA OUTPUT, CRITICAL BUCKLING LOAD

25 REF. POINTS

NO. DIRECTIONS = 3 NO. DEGREES OF FREEDOM = 2

GRIDPOINT DATA
(IN RECTANGULAR COORDINATES)

POINT	X	Y	Z	TEMPERATURES	PRESSURES
1	0.0	0.0	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
2	0.40000000E 01	0.0	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
3	0.80000000E 01	0.0	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
4	0.12000000E 02	0.0	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
5	0.16000000E 02	0.0	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
6	0.0	0.40000000E 01	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
7	0.40000000E 01	0.40000000E 01	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
8	0.80000000E 01	0.40000000E 01	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
9	0.12000000E 02	0.40000000E 01	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
10	0.16000000E 02	0.40000000E 01	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
11	0.0	0.80000000E 01	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
12	0.40000000E 01	0.80000000E 01	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
13	0.80000000E 01	0.80000000E 01	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
14	0.12000000E 02	0.80000000E 01	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
15	0.16000000E 02	0.80000000E 01	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
16	0.0	0.12000000E 02	0.0	0.0	0.0
				0.0	0.0

FIGURE III-K.14 GRIDPOINT COORDINATE DATA OUTPUT, CRITICAL BUCKLING LOAD

				0.0	0.0
17	0.40000000E 01	0.12000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
18	0.80000000E 01	0.12000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
19	0.12000000E 02	0.12000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
20	0.16000000E 02	0.12000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
21	0.0	0.16000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
22	0.40000000E 01	0.16000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
23	0.80000000E 01	0.16000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
24	0.12000000E 02	0.16000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
25	0.16000000E 02	0.16000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0

FIGURE III-K.14 GRIDPOINT COORDINATE DATA OUTPUT, CRITICAL BUCKLING LOAD (CONTINUED)

BOUNDARY CONDITION INFORMATION

NODES	DEGREES OF FREEDOM						NO. OF ONES	NO. OF TWOS
1	0	0	1	0	0	0	1	0
2	1	0	1	0	1	0	4	0
3	1	0	1	0	1	0	7	0
4	1	0	1	0	1	0	10	0
5	1	0	0	0	1	0	12	0
6	0	1	1	1	0	0	15	0
7	1	1	1	[illegible]	1	0	20	0
8	1	1	1	[illegible]	1	0	25	0
9	1	1	1	1	1	0	30	0
10	1	1	0	0	1	0	33	0
11	0	1	1	1	0	0	36	0
12	1	1	1	1	1	0	41	0
13	1	1	1	1	1	0	46	0
14	1	1	1	1	1	0	51	0
15	1	1	0	0	1	0	54	0
16	0	1	1	1	0	0	57	0
17	1	1	1	1	1	0	62	0
18	1	1	1	1	1	0	67	0
19	1	1	1	1	1	0	72	0
20	1	1	0	0	1	0	75	0
21	0	1	0	1	0	0	77	0
22	1	1	0	1	0	0	80	0
23	1	1	0	1	0	0	83	0
24	1	1	0	1	0	0	86	0
25	1	1	0	0	0	0	88	0

FIGURE III-K.15 BOUNDARY CONDITION OUTPUT, CRITICAL BUCKLING LOAD

```
TOTAL NO. ELEMENTS =

ELEM TYPE  MAT.NO. CODE   TEMP.    PRNT  NO.    --------GRID POINTS--------    EXTRA GRID PTS    ------SECTION PROPERTIES------
  1  28        1     0  0.0          2    4      1   2   7   6

MATERIAL NUMBER. . . . . . . .        1
     MATERIAL IDENTIFICATION. . . .XXXXXXXXXXXXXXXXXXXXXXXX
     ANALYSIS CAPABILITY. . . . . .  ISOTROPIC
     INPUT PRINT CODE . . . . . . .  1
     ELEMENT PRINT CODE . . . . . . -1

INTERPOLATED MATERIAL PROPERTIES
     TEMPERATURE -        0.0
     YOUNG'S MODULI          0.30000000E 08      0.30000000E 08      0.30000000E 08
     POISSON'S RATIO         0.29999995E 00      0.29999995E 00      0.29999995E 00
     TH. EXP. COEF.          0.0                 0.0                 0.0
     RIGIDITY MODULI         0.11538468E 08      0.11538468E 08      0.11538468E 08

INTERPOLATED PLASTIC PROPERTIES
     NONE

PRE-STRAIN INPUT
     NONE

PRE-STRESS INPUT
     NONE

EXTERNAL INPUT
          0.99999964E-01      0.99999964E-01      0.0               0.0               0.0

ELEM TYPE  MAT.NO. CODE   TEMP.    PRNT  NO.    --------GRID POINTS--------    EXTRA GRID PTS    ------SECTION PROPERTIES------
  2  28        1     0  0.0          2    4      2   3   8   7

MATERIAL NUMBER. . . . . . . .        1
     MATERIAL IDENTIFICATION. . . .XXXXXXXXXXXXXXXXXXXXXXXX
     ANALYSIS CAPABILITY. . . . . .  ISOTROPIC
     INPUT PRINT CODE . . . . . . .  1
     ELEMENT PRINT CODE . . . . . . -1

INTERPOLATED MATERIAL PROPERTIES
     TEMPERATURE -        0.0
     YOUNG'S MODULI          0.30000000E 08      0.30000000E 08      0.30000000E 08
     POISSON'S RATIO         0.29999995E 00      0.29999995E 00      0.29999995E 00
     TH. EXP. COEF.          0.0                 0.0                 0.0
     RIGIDITY MODULI         0.11538468E 08      0.11538468E 08      0.11538468E 08

INTERPOLATED PLASTIC PROPERTIES
     NONE

PRE-STRAIN INPUT
     NONE

PRE-STRESS INPUT
```

FIGURE III-K.16 FINITE ELEMENT DESCRIPTION OUTPUT, CRITICAL BUCKLING LOAD

```
     NONE

EXTERNAL INPUT
          0.99999964E-01     0.99999964E-01     0.0          0.0          0.0

ELEM TYPE  MAT.NO. CODE   TEMP.    PRNT  NC.   --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
   3  28       1     0   0.0        0     4     3   4   9   8                    0.1000E 00   0.1000E 00   0.0
   4  28       1     0   0.0        0     4     4   5  10   9                    0.1000E 00   0.1000E 00   0.0
   5  28       1     0   0.0        0     4     6   7  12  11                    0.1000E 00   0.1000E 00   0.0
   6  28       1     0   0.0        0     4     7   8  13  12                    0.1000E 00   0.1000E 00   0.0
   7  28       1     0   0.0        0     4     8   9  14  13                    0.1000E 00   0.1000E 00   0.0
   8  28       1     0   0.0        0     4     9  10  15  14                    0.1000E 00   0.1000E 00   0.0
   9  28       1     0   0.0        0     4    11  12  17  16                    0.1000E 00   0.1000E 00   0.0
  10  28       1     0   0.0        0     4    12  13  18  17                    0.1000E 00   0.1000E 00   0.0
  11  28       1     0   0.0        0     4    13  14  19  18                    0.1000E 00   0.1000E 00   0.0
  12  28       1     0   0.0        0     4    14  15  20  19                    0.1000E 00   0.1000E 00   0.0
  13  28       1     0   0.0        0     4    16  17  22  21                    0.1000E 00   0.1000E 00   0.0
  14  28       1     0   0.0        0     4    17  18  23  22                    0.1000E 00   0.1000E 00   0.0
  15  28       1     0   0.0        0     4    18  19  24  23                    0.1000E 00   0.1000E 00   0.0

ELEM TYPE  MAT.NO. CODE   TEMP.    PRNT  NC.   --------GRID POINTS--------   EXTRA GRID PTS   ------SECTION PROPERTIES------
  16  28       1     0   0.0        2     4    19  20  25  24

MATERIAL NUMBER. . . . . . . .      1
     MATERIAL IDENTIFICATION. . . .XXXXXXXXXXXXXXXXXXXXXX
     ANALYSIS CAPABILITY. . . . . .  ISOTROPIC
     INPUT PRINT CODE . . . . . . .  1
     ELEMENT PRINT CODE . . . . . . -1

INTERPOLATED MATERIAL PROPERTIES
     TEMPERATURE -       0.0
     YOUNG'S MODULI          0.30000000E 08     0.30000000E 08     0.30000000E 08
     POISSON'S RATIO         0.29999995E 00     0.29999995E 00     0.29999995E 00
     TH. EXP. COEF.          0.0                0.0                0.0
     RIGIDITY MODULI         0.11538468E 08     0.11538468E 08     0.11538468E 08

INTERPOLATED PLASTIC PROPERTIES
     NONE

PRE-STRAIN INPUT
     NONE

PRE-STRESS INPUT
     NONE

EXTERNAL INPUT
          0.99999964E-01     0.99999964E-01     0.0          0.0          0.0
```

FIGURE III-K.16 FINITE ELEMENT DESCRIPTION OUTPUT, CRITICAL BUCKLING LOAD (CONTINUED)

TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN

150 X 1

0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
-0.20000000E 01	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
-0.10000000E 01	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
-0.40000000E 01	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
-0.40000000E 01	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
-0.20000000E 01	0.0	0.0	0.0	0.0	0.0

T-ZERO FOR STRUCTURE = 0.0

FIGURE III-K.17 TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN OUTPUT, CRITICAL BUCKLING LOAD

GPRINT OF MATRIX LOADS (SET 1)

ROW	FX	FY	FZ	MX	MY	MZ
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
5	-0.20000000E 01	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0
10	-0.40000000E 01	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0
15	-0.40000000E 01	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0
20	-0.40000000E 01	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0
25	-0.20000000E 01	0.0	0.0	0.0	0.0	0.0

FIGURE III-K.18 LOAD OUTPUT, CRITICAL BUCKLING LOAD

DISPLACEMENT MATRIX FOR LOAD CONDITION 1

150 X 1

ROW	U	V	W	THETAX	THETAY	THETAZ
1	0.0	0.0	0.0	0.0	0.0	0.0
2	-0.13333101E-05	0.0	0.0	0.0	0.0	0.0
3	-0.26666294E-05	0.0	0.0	0.0	0.0	0.0
4	-0.39999560E-05	0.0	0.0	0.0	0.0	0.0
5	-0.53332649E-05	0.0	0.0	0.0	0.0	0.0
6	0.0	0.39999355E-06	0.0	0.0	0.0	0.0
7	-0.13333110E-05	0.39999333E-06	0.0	0.0	0.0	0.0
8	-0.26666276E-05	0.39999344E-06	0.0	0.0	0.0	0.0
9	-0.39999541E-05	0.39999509E-06	0.0	0.0	0.0	0.0
10	-0.53332851E-05	0.40000003E-06	0.0	0.0	0.0	0.0
11	0.0	0.79998756E-06	0.0	0.0	0.0	0.0
12	-0.13333128E-05	0.79998563E-06	0.0	0.0	0.0	0.0
13	-0.26666285E-05	0.79998733E-06	0.0	0.0	0.0	0.0
14	-0.39999522E-05	0.79999234E-06	0.0	0.0	0.0	0.0
15	-0.53332869E-05	0.80000291E-06	0.0	0.0	0.0	0.0
16	0.0	0.11999828E-05	0.0	0.0	0.0	0.0
17	-0.13333165E-05	0.11999819E-05	0.0	0.0	0.0	0.0
18	-0.26666348E-05	0.11999828E-05	0.0	0.0	0.0	0.0
19	-0.39999613E-05	0.11999909E-05	0.0	0.0	0.0	0.0
20	-0.53332969E-05	0.12000055E-05	0.0	0.0	0.0	0.0
21	0.0	0.15999794E-05	0.0	0.0	0.0	0.0
22	-0.13333211E-05	0.15999767E-05	0.0	0.0	0.0	0.0
23	-0.26666467E-05	0.15999813E-05	0.0	0.0	0.0	0.0
24	-0.39999768E-05	0.15999922E-05	0.0	0.0	0.0	0.0
25	-0.53333097E-05	0.16000058E-05	0.0	0.0	0.0	0.0

FIGURE III-K.19 DISPLACEMENT OUTPUT, CRITICAL BUCKLING LOAD

```
S T R E S S E S   F O R   T H E   Q U A D R I L A T E R A L   P L A T E   E L E M E N T

LOAD CONDITION NUMBER     ELEMENT NUMBER     ELEMENT TYPE     ELEMENT GRID POINTS
         1                      1                 28           1    2    7    6          0

APPARENT ELEMENT STRESSES                                               FLEXURAL MOMENTS                             SHEAR
STRESS             MEMBRANE STRESSES                       ABOUT X-AXIS   ABOUT Y-AXIS    TORQUE(MXY)    NORMAL(QX)    NORMAT(QY)
POINT      SIGMA-X         SIGMA-XY          SIGMA-Y       0.0            0.0             0.0            0.0           0.0
   1  -C.999983E C1   -0.524521E-05    0.953674E-06

ELEMENT APPLIED STRESSES                                                FLEXURAL MOMENTS                             SHEAR
STRESS             MEMBRANE STRESSES                       ABOUT X-AXIS   ABOUT Y-AXIS    TORQUE(MXY)    NORMAL(QX)    NORMAT(QY)
POINT      SIGMA-X         SIGMA-XY          SIGMA-Y       0.0            0.0             0.C            0.0           0.0
   1   C.0             0.0               0.0

NET ELEMENT STRESSES                                                    FLEXURAL MOMENTS                             SHEAR
STRESS             MEMBRANE STRESSES                       ABOUT X-AXIS   ABOUT Y-AXIS    TORQUE(MXY)    NORMAL(QX)    NORMAT(QY)
POINT      SIGMA-X         SIGMA-XY          SIGMA-Y       0.0            0.0             0.0            0.0           0.0
   1  -C.999983E C1   -0.524521E-05    0.953674E-06
```

FIGURE III-K.20 STRESS OUTPUT, ELEMENT NO. 1, CRITICAL BUCKLING LOAD

```
S T R E S S E S   F O R   T H E   Q U A D R I L A T E R A L   P L A T E   E L E M E N T

   LOAD CONDITION NUMBER     ELEMENT NUMBER     ELEMENT TYPE      ELEMENT GRID POINTS
            1                      16                 28            19   20   25   24

APPARENT ELEMENT STRESSES
STRESS            MEMBRANE STRESSES                                    FLEXURAL MOMENTS                                        SHEAR
POINT       SIGMA-X          SIGMA-XY        SIGMA-Y          ABOUT X-AXIS   ABOUT Y-AXIS     TORQUE(MXY)     NORMAL(QX)      NORMAL(QY)
    1  -0.100000E 02  -0.133514E-04  -0.667572E-05   0.0            0.0              0.0             0.0             0.0

ELEMENT APPLIED STRESSES
STRESS            MEMBRANE STRESSES                                    FLEXURAL MOMENTS                                        SHEAR
POINT       SIGMA-X          SIGMA-XY        SIGMA-Y          ABOUT X-AXIS   ABOUT Y-AXIS     TORQUE(MXY)     NORMAL(QX)      NORMAL(QY)
    1   0.0              0.0             0.0              0.0            0.0              0.0             0.0             0.0

NET ELEMENT STRESSES
STRESS            MEMBRANE STRESSES                                    FLEXURAL MOMENTS                                        SHEAR
POINT       SIGMA-X          SIGMA-XY        SIGMA-Y          ABOUT X-AXIS   ABOUT Y-AXIS     TORQUE(MXY)     NORMAL(QX)      NORMAL(QY)
    1  -0.100000E 02  -0.133514E-04  -0.667572E-05   0.0            0.0              0.0             0.0             0.0
```

FIGURE III-K.21 STRESS OUTPUT, ELEMENT NO. 16, CRITICAL BUCKLING LOAD

```
EIGENVALUE     1
-0.95970668E-02

SQUARE ROOT OF EIGENVALUE
0.97964585E-01

FREQUENCY  = 1 / SQUARE ROOT OF EIGENVALUE
             0.10207770E 02     RADIANS/SECOND
             0.16246166E 01     CYCLES/SECOND
```

FIGURE III-K.22 LOWEST BUCKLING LOAD AND ASSOCIATED MODE SHAPE OUTPUT, CRITICAL BUCKLING LOAD

DEFLECTION = EIGENVECTOR
88 X 1

ROW						
1	0.0	0.0	0.10000000E 01	0.0	0.0	0.0
2	0.0	0.0	0.92390394E 00	0.0	0.37567206E-01	0.0
3	0.0	0.0	0.70716709E 00	0.0	0.69427848E-01	0.0
4	0.0	0.0	0.38274390E 00	0.0	0.90729117E-01	0.0
5	0.0	0.0	0.0	0.0	0.99212481E-01	0.0
6	0.0	0.0	0.92387873E 00	-0.37571540E-01	0.0	0.0
7	0.0	0.0	0.85357618E 00	-0.34717385E-01	0.34707099E-01	0.0
8	0.0	0.0	0.65333998E 00	-0.26572905E-01	0.64142704E-01	0.0
9	0.0	0.0	0.35361183E 00	-0.14381882E-01	0.83822906E-01	0.0
10	0.0	0.0	0.0	0.0	0.90737045E-01	0.0
11	0.0	0.0	0.70710731E 00	-0.69434285E-01	0.0	0.0
12	0.0	0.0	0.65329999E 00	-0.64150651E-01	0.26563372E-01	0.0
13	0.0	0.0	0.50004792E 00	-0.49101762E-01	0.49092691E-01	0.0
14	0.0	0.0	0.27064437E 00	-0.26575428E-01	0.64155636E-01	0.0
15	0.0	0.0	0.0	0.0	0.69447815E-01	0.0
16	0.0	0.0	0.38268602E 00	-0.90721011E-01	0.0	0.0
17	0.0	0.0	0.35356706E 00	-0.83817720E-01	0.14376041E-01	0.0
18	0.0	0.0	0.27062678E 00	-0.64155579E-01	0.26568733E-01	0.0
19	0.0	0.0	0.14647228E 00	-0.34723230E-01	0.34721073E-01	0.0
20	0.0	0.0	0.0	0.0	0.37584987E-01	0.0
21	0.0	0.0	0.0	-0.98156149E-01	0.0	0.0
22	0.0	0.0	0.0	-0.90724051E-01	0.0	0.0
23	0.0	0.0	0.0	-0.69442153E-01	0.0	0.0
24	0.0	0.0	0.0	-0.37584309E-01	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE III-K.22 LOWEST BUCKLING LOAD AND ASSOCIATED MODE SHAPE OUTPUT, CRITICAL BUCKLING LOAD (CONTINUED)

L. PORTAL FRAME (Vibration Analysis with Condensation)

A portal frame is shown in Figure III-L.1 along with its dimensions and pertinent material properties. This example demonstrates the use of the DYNAMICSC Abstraction Instructions. A mode and frequency analysis is performed using the technique of condensation (Guyan reduction).

The preprinted input data forms associated with this example are displayed in Figures III-L.2 thru III-L.11.

In Figure III-L.3, Material Tape Input Section, note that the mass density value is entered in columns 55 thru 64. This is a required entry in vibration analyses as this value is used in generating consistent mass matrices at the element level.

In Figure III-L.6, Boundary Condition Section, note that certain degrees-of-freedom at selected grid points are eliminated (condensed) by means of Guyan reduction. For example, at Grid Point Number 2, the V and the θ_z degree-of-freedom are eliminated. This is accomplished by entering the integer '2' opposite Grid Point Number 2 in the locations corresponding to V and θ_z. As further examples, the θ_z degree of freedom is eliminated (condensed) at Grid Points 3, 4 and 5 respectively.

In the DYNAM Section (Figure III-L.7) note that the first five eigenvalues and eigenvectors are requested for this analysis.

In Figure III-L.10 (Element Input) it is noted that only the MODAL entry is used. This means that all of the Frame Elements used in this analysis have identical Element Input as follows:

Location A - Cross-Sectional Area (A) = 18.0 in^2

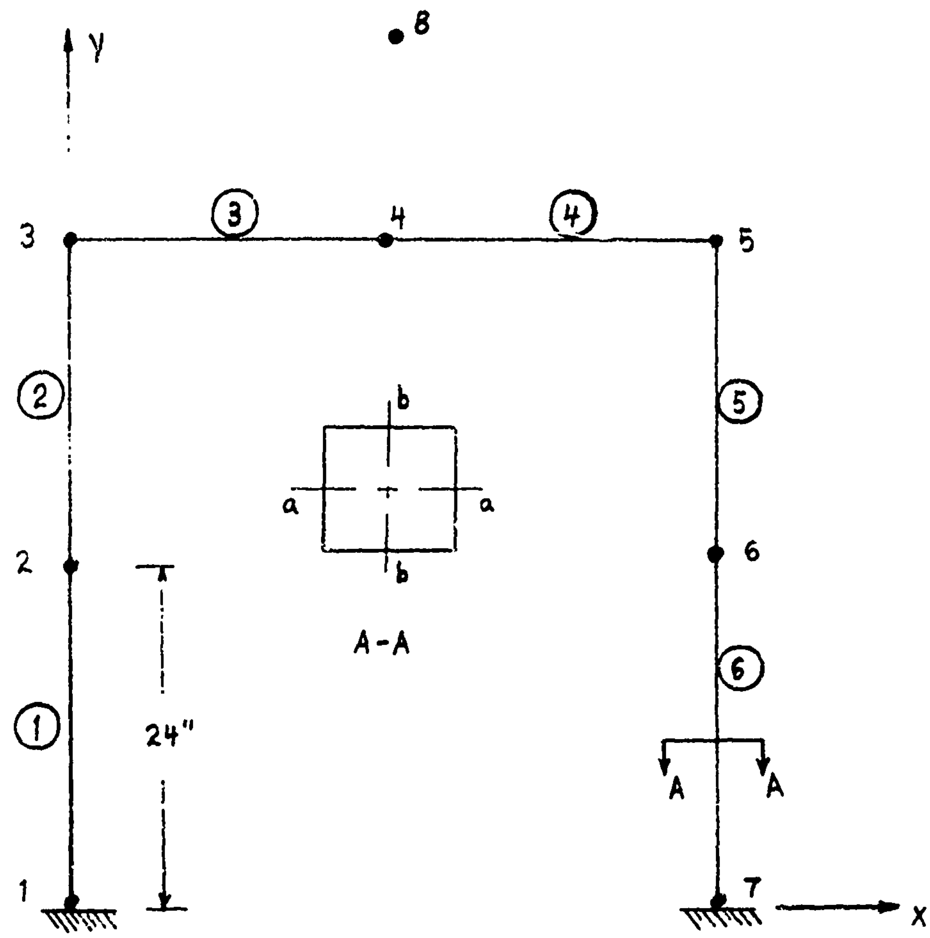
Location B - Area Moment of Inertia (I_{zz}) = 13.5 in^4

Location C - Area Moment of Inertia (I_{yy}) = 13.5 in^4

Location D - Torsional Moment of Inertia (J) = 27.0 in^4

The output supplied by the MAGIC System for the portal frame vibration analysis is as follows.

Figure III-L.12 shows the matrix abstraction instructions (DYNAMICSC) associated with this particular problem. A complete discussion of these instructions is provided on pages 87 thru 90 of this report.



$E = 10^7$ PSI

$A = 18$ IN^2

$\mu = 0.30$

$\rho = 0.00025879$ LB-SEC^2/IN/IN^3

$I_a = I_b = 13.5$ IN^4

FIGURE III-L.1 IDEALIZED PORTAL FRAME (VIBRATION ANALYSIS WITH CONDENSATION)

BAC 1615

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

TITLE INFORMATION

REPORT (/)

THIS IS THE FIRST ENTRY ON ALL REPORT FORM INPUT RUNS AND IT IS REQUIRED FOR ALL RUNS.

TITLE (/)

5 (/) NUMBER OF TITLE CARDS

PORTAL FRAME NORMAL MODE AND FREQUENCY ANALYSIS (WITH CONDENSATION) (/

6 ELEMENTS 8 NODES - S. JORDAN 20 OCTOBER 1967 (/

REFERENCE BISHOP R. E. D. THE ANALYSIS OF VIBRATING SYSTEMS WHICH (/

EMBODY BEAMS IN FLEXURE PROC. INST. MECH. ENGRS. 169, 1031-1050(1955) (/

REFERENCE PROVIDES AN ANALYTICAL SOLN. WITHOUT STRETCHING (/

(/

(/

(/

(/

(/

Figure III-L.2 Title Information, Portal Frame

BAC 1616-1

MATER (/)
1 2 3 4 5 6

1 (/)
7 8 9
No. of Requests

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MATERIAL TAPE INPUT

Request Number	Material Number	Lock Code	Material Identification	Isotropic	Orthotropic	Plastic Isotropic	Plastic Orthotronic	Add Plastic	Delete Material	Print Tape	Print Mat'l. Table	Print Mat'l. Summary	Number of Mat'l. Pts.	Number of Plastic Pts.	Mass Density	
7–9	10–15	16–17	18–41	42	43	44	45	46	47	48	49	50	51–52	53–54	55–64	
1	1	2ST	ALUMINUM PORTAL FRAME	X									2		0.25879E-3	(/)

MATERIAL PROPERTIES TABLE

Temperature (13–22)	Direction	Youngs Moduli (23–32)	Direction	Poissons Ratios (33–42)	Direction	Coef. of Thermal Expansion (43–52)	Direction	Rigidity Moduli (53–62)	
0.0	E_x	0.100 E8	ν_{xy}	0.30	α_x		G_{xy}		(/)
	E_y		ν_{yz}		α_y		G_{yz}		(/)
	E_z		ν_{zx}		α_z		G_{zx}		(/)
0.0		0.100 E8		0.30					(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)
									(/)

Figure III-L.3 Material Tape Input, Portal Frame

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

SYSTEM CONTROL INFORMATION

> ENTER APPROPRIATE NUMBER, RIGHT ADJUSTED, IN BOX OPPOSITE APPLICABLE REQUESTS

S	Y	S	T	E	M
1	2	3	4	5	6

(/)

Item	Request	Entry	Columns
1.	Number of System Grid Points	8	1 2 3 4 5 6
2.	Number of Input Grid Points	8	7 8 9 10 11 12
3.	Number of Degrees of Freedom/Grid Point	6	13 14
4.	Number of Load Conditions	1	15 16
5.	Number of Initially Displaced Grid Points		17 18 19 20 21 22
6.	Number of Prescribed Displaced Grid Points		23 24 25 26 27 28
7.	Number of Grid Point Axes Transformation Systems		29 30
8.	Number of Elements	6	31 32 33 34 35 36
9.	Number of Requests and/or Revisions of Material Tape.	1	37 38
10.	Number of Input Boundary Condition Points	8	39 40 41 42 43 44
11.	T_o For Structure (With Decimal Point)	0.0	45 46 47 48 49 50 51 52

(/)

Figure III-L.4 System Control Information, Portal Frame

BAC 1672

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

1 2 3 4 5 6

C	O	O	R	D	

(/)

GRIDPOINT COORDINATE

COORD. INPUT	$\not{S}$
SYSTEM: RECTANGULAR	R/Δ
SYSTEM: CYLINDRICAL	C
SYSTEM: SPHERICAL	S

Δ = BLANK

$ (5)	(6)	Grid Point Number (7–12)	DIRECTIONS X – R (13–22)	DIRECTIONS Y – Θ (23–32)	DIRECTIONS Z – Z (33–42)	
		1	0.0	0.0	0.0	(/)
		2	0.0	24.00	0.0	(/)
		3	0.0	48.00	0.0	(/)
		4	24.00	48.00	0.0	(/)
		5	48.00	48.00	0.0	(/)
		6	48.00	24.00	0.0	(/)
		7	24.00	0.0	0.0	(/)
		8	24.00	40.00	0.0	(/)

If coordinate information must be continued on second sheet, user MUST delete Coord. Label Card from second sheet.

Figure III-L.5 Gridpoint Coordinates, Portal Frame

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

BOUNDARY CONDITIONS

INPUT CODE - 0 - No Displacement Allowed
1 - Unknown Displacement
2 - Known Displacement

1	2	3	4	5	6
B	O	U	N	D	

(/)

PRE-SET MODE

1	2	3	4	5	6
M	O	D	A	L	

TRANSLATIONS			ROTATIONS			GENERALIZED		
U	V	W	θx	θy	θz	1	2	3
13	14	15	16	17	18	19	20	21
									(/)

LISTED INPUT

Grid Point Number (7-11)	Repeat (12)	13	14	15	16	17	18	19	20	21	
1		0	0	0	0	0	0				(/)
2		1	2	0	0	0	2				(/)
3		1	1	0	0	0	2				(/)
4	X										(/)
5	X										(/)
6		1	2	0	0	0	2				(/)
7		0	0	0	0	0	0				(/)
8	X										(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)
											(/)

Figure III-L.6 Boundary Conditions, Portal Frame 502

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

DYNAMICS INFORMATION

D	Y	N	A	M		(/)
1	2	3	4	5	6	

1. Number of Eigenvalues Requested
   (Less than or Equal to 20)
   Columns 1 2: [ ][5]

2. Convergence Criteria (Floating Point)
   (Default Option - 0.001)
   Columns 3 4 5 6 7 8 9 10 11 12 13 14

3. Maximum Number of Iterations
   (Default Option - 500 iterations)
   Columns 15 16 17

4. Debug Iteration Print
   Iteration Print ON = 1
   Iteration Print OFF = 0
   (Default Option - Print OFF)
   Column 18

5. First Normalizing Element for Print
   (Default Option - No First Normalization)
   Columns 19 20 21 22

6. Second Normalizing Element for Print
   (Default Option - No Second Normalization)
   Columns 23 24 25 26

7. Control for Guess Vector Iteration Start
   Column Iteration Start = 0
   Row Iteration Start = 1
   (Default Option - Column Iteration Start)
   Column 27 (/)

Figure III-L.7 Dynamics Information, Portal Frame

SAC 1627

LOADS

LCASE | Condition Number | Scale | 1.0

Transformation Code For Loads

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

MODS

EXTERNAL LOADS

Grid Pt. Number	FORCE VALUES F_x	FORCE VALUES F_y	FORCE VALUES F_z	MOMENT VALUES M_x	MOMENT VALUES M_y	MOMENT VALUES M_z	GENERALIZED VALUES 1	GENERALIZED VALUES 2	GENERALIZED VALUES 3
1	0.0	0.0	0.0	0.0	0.0	0.0			

[illegible] External Loads, [illegible] Frame

[illegible]

DAC 1020

ELEM (/)

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

ELEMENT CONTROL DATA

ELEMENT NUMBER (7-10)	PLUG NO. (11-12)	MATERIAL NUMBER (13-18)	Interpolate Option (19)	MATERIAL TEMPERATURE (20-27)	Repeat Elem. Matrices (28)	Elem. Input (29)	PRINT Print (30)	PRINT Elem. Mat. (31)	PRINT Full (32)	Number of Input Nodes (33-34)	Suppress Pressures (35)	NODE POINTS 1	2	3	4	5	6	7	8	9	10	11	12
1	1	12				X				3		1	2	8									
2	1	12				X				3		2	3	8									
3	1	12				X				3		3	4	8									
4	1	12				X				3		4	5	8									
5	1	12				X				3		5	6	8									
6	1	12				X				3		6	7	8									

Figure III-I.9 Element Control Data, Portal Frame

Page ______ of ______

BAC 1629-1

MAGIC STRUCTURAL ANALYSIS SYSTEM
INPUT DATA FORMAT

E X T E R N (/)

1 2 3 4 5 6

ELEMENT INPUT

1 2 3 4 5 6	A (13–22)	B (23–32)	C (33–42)	D (43–52)	E (53–62)	F (63–72)
MODAL	18.0	13.50	13.50	27.00		

Element Number (7–11)	Repeat (12)	A (13–22)	B (23–32)	C (33–42)	D (43–52)	E (53–62)	F (63–72)	
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)
								(/)

Figure III-L.10 Element Input, Portal Frame

Page ______ of ______

MAGIC STRUCTURAL ANALYSIS SYSTEM

INPUT DATA FORMAT

CHECK OR END CARD

C	H	E	C	K	(/)
1	2	3	4	5	

E	N	D	(/)
1	2	3	

Figure III-L.11 End Card, Portal Frame

Figures III-L.13 thru III-L.16 display the output from the Structural Systems Monitor. These figures record the input data pertiment to the problem being solved.

Figure III-L.14 displays the coordinate and boundary condition information. In the Boundary Condition Information Section of the figure, zeros ('0') represent degrees-of-freedom that are fixed, ones ('1') represent degrees-of-freedom that have unknown values of displacement and twos ('2') represent degrees-of-freedom that are to be condensed (eliminated) from the system. The last two columns list the cumulative total of ones and twos for this analysis. Note that for this case, a total of 7 degrees-of-freedom are condensed from the system.

MAGIC System output of final results is displayed in Figures III-L.17 thru III-L.24.

Figure III-L.17 shows the reduced (uncondensed) stiffness matrix for this problem. The stiffness matrix is presented row-wise and is shuffled so that the degrees-of-freedom corresponding to ones ('1') occupy the first eight rows and columns of the matrix while the degrees-of-freedom associated with twos ('2') occupy the last seven rows and columns of the stiffness matrix.

Figure III-L.18 displays the reduced (uncondensed) mass matrix for this problem. Note that its ordering is consistent with the Stiffness Matrix of Figure III-L.17.

Figures III-L.19 and III-L.20 display selected mode shapes and frequencies for this application.

Figure III-L.19 displays the results predicted for the first natural frequency and its associated mode shape. In an analogous manner, Figure III-L.20 displays the fifth predicted natural frequency with its associated mode shape.

Note that for both cases, the mode shape is normalized on the largest element contained in the eigenvector.

Figure III-L.21 displays the generalized mass and stiffness matrices for this application. Note the diagonal nature of these matrices which verifies the orthogonality of the predicted eigenvectors.

Figure III-L.22 displays the dynamic matrix (MATRIX DYNAM). This matrix is the product of the following:

$$\left[DYNAM\right] = \left[K_R\right]^{-1} \left[M_R\right]$$

where $\left[K_R\right]$ is the reduced, condensed stiffness matrix (8 x 8)

and $\left[M_R\right]$ is the reduced condensed mass matrix (8 x 8)

As final items of information, Figures III-L.23 and III-L.24 display the reduced condensed stiffness matrix (MATRIX K_R) and mass matrix (MATRIX M_R) respectively. These matrices are of the order 8 x 8 since a total of 7 degrees-of-freedom were condensed from the system in this particular analysis.

ABSTRACTION SOURCE TEST 5..


```
        C
        C----- DYNAMICS AGENDUM, WITH CONDENSATION
        C
        C-----DYNAMICS AGENDUM ANALYSIS
        C
        C        DYNAMICS ANALYSIS INSTRUCTION SEQUENCE
        C
                 GENERATE ELEMENT MATRICES
        .
  1          ,MLIB,,,TH,,KEL,,,,,MEL,SC,EM, = ,,, .USER 4.
        C
        C        ASSEMBLE STIFFNESS MATRIX AND MASS MATRIX
        C
  2          STIFF = EK .ASSEM. SC,(1)
  3          MASS = EM .ASSEM. SC,(2)
        C
        C        PRINT STIFFNESS MATRIX AND MASS MATRIX
  4          PRINT(FORCE,DISP,,) STIFF
        C
  5          PRINT(FORCE,ACCEL,,) MASS
        C
        C        GENERATE DYNAMICS MATRIX
        C
  6          TOP,BOT  = STIFF .DEJOIN. (SC(6,1),1)
  7          K11,K12  = TOP .DEJOIN. (SC(6,1),0)
  8          K12T,K22 - BOT.DEJOIN. (SC(6,1),0)
  9          K22I = -K22 .INVERS.
 10          KR1  = K22I .MULT. K12T
 11          KR2  = K12  .MULT. KR1
 12          KR   = K11  .ADD.  KR2
 13          IDENT = K11 .IDENTR.
 14          KR1T = KR1 .TRANSP.
 15          GAMT  = IDENT .ADJOIN. KR1T
 16          GAM   = GAMT .TRANSP.
 17          MR1  = GAMT .MULT. MASS
 18          MR   = MR1 .MULT. GAM
 19          KRI = KR .INVERS.
 20          DYNAM = KRI .MULT. MR
```

FIGURE III-L.12 DYNAMICSC ABSTRATION INSTRUCTION LISTING

```
      C
      C        FIND E-VALUES, E-VECTORS, NORMAL MODES,
      C        FREQUENCIES AND PRINT
      C
           EVALUE,,EVECT,, = DYNAM, .EIGEN1. SC
      C
           TR 1, TR 2 = TR .DEJOIN. (SC(8,1),1)
           TR ,TR : = TRC1 .DEJOIN. (SC(5,1),1)
           GPRINT ( ,,,,,, ,TR1) EVECT,EVALUE
      C
      C        GENERATE STIFFNESS AND GENERALIZED MASS
      C        MATRICES AND PRINT
```

NOT REPRODUCIBLE


```
      C
 25        KGEN1 = EVECT.TMULT.KR
 26        KGEN = KGEN1.MULT.EVECT
 27        MGEN1 = EVECT.TMULT.MR
 28        MGEN = MGEN1.MULT.EVECT
      C
 29        PRINT(,,,) MGEN,KGEN,DYNAM,KR,MR
```

FIGURE III-L.12 DYNAMICSC ABSTRATION INSTRUCTION LISTING (CONTINUED)

PORTAL FRAME NORMAL MODE AND FREQUENCY ANALYSIS (WITH COMPENSATION)

6 ELEMENTS 5 NODES - S.JOHNSON . OCTOBER 1967

REFERENCE* BISHOP R.E.D. THE ANALYSIS OF VIBRATING SYSTEMS WHICH

EMBODY BEAMS IN FLEXURE PROC. INST. MECH. ENGRS. 1955 21-1057(1955)

REFERENCE PROVIDES AN ANALYTICAL SOLN. WITHOUT STRETCHING

REVISIONS OF MATERIAL TAPE

ASTERISK (*) PRECEEDING MATERIAL
IDENTIFICATION INDICATES THAT INPUT
ERROR RETURNS WILL NOT RESULT IN
TERMINATION OF EXECUTION

****

```
REVISION
 MATERIAL NUMBER      12
 MATERIAL IDENTIFICATION  ALUMINUM PORTAL FRAME            INPUT CODE   I
   NUMBER OF MATERIAL PROPERTY POINTS. . . .  2
   NUMBER OF PLASTIC PROPERTY POINTS . . . .  0
   MASS DENSITY. . . . . . . . . . . . . . . 0.2587998E-03

 MATERIAL PROPERTIES
```

	YOUNG'S MODULI			POISSON'S RATIOS		
	DIRECTIONS			DIRECTIONS		
TEMPERATURE	XX	YY	ZZ	XY	YZ	ZX
0.0	0.100000E 08	0.100000E 08	0.100000E 08	0.300000E 00	0.300000E 00	0.300000E 00
0.0	0.100000E 08	0.100000E 08	0.100000E 08	0.300000E 00	0.300000E 00	0.300000E 00

	TH. EXP.COEF.			RIGIDITY MODULI		
	DIRECTIONS			DIRECTIONS		
TEMPERATURE	XX	YY	ZZ	XY	YZ	ZX
0.0	0.0	0.0	0.0	0.384616E 07	0.384616E 07	0.384616E 07
0.0	0.0	0.0	0.0	0.384616E 07	0.384616E 07	0.384616E 07

****

FIGURE III-L.13 TITLE AND MATERIAL DATA OUTPUT, PORTAL FRAME

NO. POINTS

NO. DIRECTIONS = 3 NO. DEGREES OF FREEDOM =

GRIDPOINT DATA
(IN RECTANGULAR COORDINATES)

NOT REPRODUCIBLE

POINT	X	Y	Z	TEMPERATURES	PRESSURES
1	0.0	0.0	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
2	0.0	0.24000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
3	0.0	0.48000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
4	0.24000000E 02	0.48000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
5	0.48000000E 02	0.48000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
6	0.48000000E 02	0.24000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
7	0.24000000E 02	0.0	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0
8	0.24000000E 02	0.40000000E 02	0.0	0.0	0.0
				0.0	0.0
				0.0	0.0

BOUNDARY CONDITION INFORMATION

NODES	DEGREES OF FREEDOM						NO. OF ONES	NO. OF TWOS
1	0	0	0	0	0	0	0	0
2	1	2	0	0	0	2	1	2
3	1	1	0	0	0	2	3	3
4	1	1	0	0	0	2	5	4
5	1	1	0	0	0	2	7	5
6	1	2	0	0	0	2	8	7
7	0	0	0	0	0	0	8	7
8	0	0	0	0	0	0	8	7

FIGURE III-L.14 GRIDPOINT DATA AND BOUNDARY CONDITION OUTPUT, PORTAL FRAME

TOTAL NO. ELEMENTS =

ELEM	TYPE	MAT.NO.	CODE	TEMP.	PRNT	NO.	GRID POINTS			EXTRA GRID PTS	SECTION PROPERTIES		
1	11	12	0	0.0	0	3	1	2	[illegible]		0.1800E 02	0.1350E 02	0.1350E 02
											0.2700E 02	0.0	
2	11	12	0	0.0	0	3	2	3	9		0.1800E 02	0.1350E 02	0.1350E 02
											0.2700E 02	0.0	
3	11	12	0	0.0	0	3	3	4	9		0.1800E 02	0.1350E 02	0.1350E 02
											0.2700E 02	0.0	
4	11	12	0	0.0	0	3	4	5	8		0.1800E 02	0.1350E 02	0.1350E 02
											0.2700E 02	0.0	
5	11	12	0	0.0	0	3	5	6	8		0.1800E 02	0.1350E 02	0.1350E 02
											0.2700E 02	0.0	
6	11	12	0	0.0	0	3	6	7	8		0.1800E 02	0.1350E 02	0.1350E 02
											0.2700E 02	0.0	

FIGURE III-L.15 FINITE ELEMENT DESCRIPTION OUTPUT, PORTAL FRAME

EXTER[illegible] LOAD CONDITIONS

LOAD NO. 1

NUMBER OF LOADED NODES 1 ELEMENT LOAD SCALAR = [illegible]

TRANSFORMED EXTERNAL ASSEMBLED LOAD COLUMN

[illegible] X 1

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0
0.0	[illegible]	[illegible]	[illegible]	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0
[illegible]	0.0	[illegible]	[illegible]	0.0	0.0

T-ZERO FOR STRUCTURE = 0.0

FIGURE III-L.16 TRANSFORMED EXTERNAL LOAD COLUMN, PORTAL FRAME

NOT REPRODUCIBLE

MATRIX STIFF

PAGE 1

CUTOFF = .

SIZE 15 BY 15

		FORCE		FORCE		FORCE		FORCE		FORCE	
DISP	1	1	[illegible].234374E 06	[illegible]	-.117187[illegible]	[illegible]	[illegible]	11	-[illegible].140625E [illegible]		
DISP	2	1	-[illegible].117187E 06	4	.761718E 7	4	-.749999E 07	10	[illegible].140625E 07	11	0.140625E 07
DISP	3	2	.761718E 07	5	-.117187E 06	9	-[illegible].749999E 07	11	0.140625E 07	12	0.140625E 07
DISP	4	2	-[illegible].749999E 7	[illegible]	[illegible] E [illegible]	6	-[illegible].749999E 07				
DISP	5	3 13	-.117187E [illegible] [illegible].140625E 7	5	.234374E 06	7	-[illegible].117187E 06	11	-0.140625E 07	12	-0.200000E 01
DISP	6	4	-[illegible].749999E 07	6	.761718E 07	5	-.117187E 06	13	0.140624E 07	15	0.140625E 07
DISP	7	5	-0.117187E 06	7	[illegible].761718E 07	12	-0.140625E 07	13	-0.140625E 07	14	-0.749999E 07
DISP	8	6	-0.117187E 06	8	[illegible].278955E 07	13	-[illegible].140625E 07	14	0.263053E 07	15	-0.509064E 06
DISP	9	3	-0.749999E 07	9	0.150[illegible]00E 08						
DISP	10	1	0.400000E 01	2	[illegible].140625E 07	1[illegible]	[illegible].449999E 08	11	0.112500E 08		
DISP	11	1 11	-0.140625E 07 0.449999E 08	2 12	[illegible].140625E [illegible]7 [illegible].112500E [illegible]	3	[illegible].140625E 07	5	-0.140625E 07	10	0.112500E 08
DISP	12	3 13	0.140625E 07 0.112500E 08	5	-[illegible].200[illegible] E [illegible]1	7	-[illegible].140625E 07	11	0.112500E 08	12	0.449999E 08
DISP	13	5 13	0.140625E 07 0.449999E 08	6 15	[illegible].140624E 07 [illegible].1125[illegible] E 08	7	-[illegible].140625E 07	8	-0.140625E 07	12	0.112500E 08
DISP	14	7	-0.749999E 07	8	0.263[illegible]93E 07	14	0.101724E 08	15	-0.497184E 06		
DISP	15	6	0.140625E 07	8	-[illegible].909[illegible]64E 06	13	[illegible].112500E 08	14	-0.497184E 06	15	0.384098E 08

FIGURE III-L.17 REDUCED (UNCONDENSED) STIFFNESS MATRIX. PORTAL FRAME

MATRIX MASS

CUTOFF = .

		FORCE		FORCE		FORCE		FORCE		FORCE	
ACCEL	1	1	.83?524E-?	4	[illegible]	11	[illegible]				
ACCEL	4	5	.143745E-?1	2	[illegible]	4	[illegible]	1	-0.830523E-01	11	0.140550E 00
ACCEL	3	3	0.787533E-?1	5	[illegible]	9	0.186336E- 1	11	[illegible]	12	-0.830523E-01
ACCEL	4	2	0.186336E-?1	4	[illegible]	6	[illegible]				
ACCEL	5	3	0.143745E-?1	5	[illegible]	7	0.143745E-?1	11	[illegible]	13	-0.830523E-01
ACCEL	6	4	0.186336E-?1	4	[illegible]	8	[illegible]	13	0.140550E 00	15	-0.830523E-01
ACCEL	7	5	0.143745E-01	7	.747933E-?1	12	0.830523E-01	13	-0.140550E 00	14	0.186336E-01
ACCEL	8	6	0.143745E-01	8	[illegible]	13	0.830523E-01	14	-0.301163E-02	15	0.582178E-01
ACCEL	9	3	0.186336E-?1	9	.745347E- 1						
ACCEL	10	2	-0.830523E-01	1	.122662E ?1	11	-0.459983E 00				
ACCEL	11	1 11	0.830523E-01 0.122662E 01	4 12	.140550E 00 -0.459983E 00	3	0.140550E 00	5	0.830523E-01	10	-0.459983E 00
ACCEL	12	3	-0.830523E-01	7	0.830523E-01	11	-0.459983E 00	12	0.122662E 01	13	-0.459983E 00
ACCEL	13	5 13	-0.830523E-01 0.122662E 01	6 15	.140550E 00 -0.459983E 00	7	-0.140550E 00	9	.830523E-01	12	-0.459983E 00
ACCEL	14	7	0.186336E-01	8	-0.301163E-02	14	0.929824E-01	15	-0.198768E 00		
ACCEL	15	6	-0.830523E-01	8	0.582178E-01	13	-0.459983E 00	14	-0.198768E 00	15	0.234801E 01

FIGURE III-L.18 REDUCED (UNCONDENSED) MASS MATRIX, PORTAL FRAME

NOT REPRODUCIBLE

EIGENVALUE 1
.2..43645E-.4

SQUARE ROOT OF EIGENVALUE
..571596 .E-.2

FREQUENCY = 1 / SQUARE ROOT OF EIGENVALUE
0.174918111E .3 RADIANS/SECOND
..27839.81E .2 CYCLES/SECOND

DEFLECTION = EIGENVECTOR
8 X 1

ROW						
1	0.C	[illegible]	[illegible]	[illegible]	C.0	0.0
2	..389471711E 0.	0..	[illegible]	[illegible]	C.C	0.0
3	0.599433377E CC	C.115831 ..E-.2	[illegible]	[illegible]	0.C	0.0
4	C.599942006E .0	-0.27735.6.E ..	[illegible]	[illegible]	C.G	0.0
5	0.10000000E .1	-0.483.4655E	[illegible]	[illegible]	0.G	0.0
6	..481493312E .C	0..	[illegible]	[illegible]	G.G	0.0
7	0.G	[illegible]	[illegible]	[illegible]	G.G	0.0
8	0.C	0..	[illegible]	[illegible]	0.C	0.0

FIGURE III-L.19 FREQUENCY AND MODE SHAPE RESULTS, MODE 1, PORTAL FRAME

EIGENVALUE
.[illegible]E-

SQUARE ROOT OF EIGENVALUE
.17154[illegible]42E-

FREQUENCY = 1 / SQUARE ROOT OF EIGENVALUE
.5[illegible]2[illegible]5273E 04 RADIANS/SECOND
.927798 10E 03 CYCLES/SECOND

DEFLECTION = EIGENVECTOR
8 X 1

ROW						
1	0.0	0.[illegible]	[illegible]	[illegible]	0.0	0.0
2	-0.75009800E-02	0.[illegible]	[illegible]	0.[illegible]	0.0	0.0
3	0.14234331E-01	0.10[illegible]E 01	[illegible]	[illegible]	0.0	0.0
4	0.43600447E-01	-0.17526698E [illegible]	[illegible]	[illegible]	0.0	0.[illegible]
5	0.52570369E-01	-0.6562[illegible]55[illegible]E-01	[illegible]	0.0	0.0	0.0
6	-0.18617499E 00	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	[illegible]	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0

FIGURE III-L.20 FREQUENCY AND MODE SHAPE RESULTS, MODE 5, PORTAL FRAME

PAGE 1

MATRIX MGEN

SIZE 5 BY 5

CUTOFF = [illegible]

	ROW		ROW		ROW		ROW		ROW	
COL	1	1	0.418545E 00	2	-.2[illegible]7126E-04	3	[illegible].439564E-06	4	-[illegible].487268E-05	5	-0.250372E-04
COL	2	1	-0.207759E-04	2	0.324820E 00	3	-0.252239E-04	4	[illegible].238190E-06	5	-0.[illegible]32717E-06
COL	3	1	0.651526E-06	2	-0.250041E-04	3	0.309920E 00	4	-0.318546E-03	5	0.439584E-06
COL	4	1	-0.470877E-05	2	.53[illegible]746E-06	3	-[illegible].318624E-03	4	0.143252E 00	5	-0.461470E-05
COL	5	1	-0.236409E-04	2	-[illegible].551343E-06	3	[illegible].473112E-06	4	-0.463426E-05	5	0.116536E 00

PAGE 1

MATRIX KGEN

SIZE 5 BY 5

CUTOFF = 0.0

	ROW		ROW		ROW		ROW		ROW	
COL	1	1	0.128097E 05	2	0.494141E 01	3	-0.130469E 01	4	-0.[illegible]03984E 01	5	0.325000E 01
COL	2	1	0.221191E 01	2	0.131125E 04	3	0.152500E 02	4	-0.213281E 01	5	-0.368750E 01
COL	3	1	-0.182349E 01	2	0.149102E 02	3	0.569044E 06	4	-0.604648E 03	5	0.25625[illegible] 01
COL	4	1	-0.176410E 00	2	-0.223828E 01	3	-[illegible].605211E 03	4	0.395762E 06	5	-0.214375E [illegible]
COL	5	1	0.338354E 01	2	-0.401563E 01	3	[illegible].275000E 01	4	-0.215234E 02	5	0.396022E 07

FIGURE III-L.21 GENERALIZED MASS AND STIFFNESS MATRICES, PORTAL FRAME

MATRIX DYNAM PAGE 1

CUTOFF = [illegible] SIZE 8 BY 8

		ROW		ROW		ROW		ROW		ROW	
COL	1	1	0.217252E-05	2	[illegible].413342E-05	3	[illegible]21.58E-05	4	0.413697E-05	5	-0.687139E-06
		6	0.412844E-05	7	-[illegible].175745E-05	8	[illegible].1756[illegible]5E-05				
COL	2	1	0.320192E-05	2	[illegible].798164E-05	3	[illegible].941893E-08	4	0.797528E-05	5	-0.186341E-05
		6	0.797426E-05	7	-[illegible].354897E-05	8	[illegible].354274E-05				
COL	3	1	-0.178238E-06	2	-0.585203E-06	3	[illegible].315821E-07	4	-0.584595E-06	5	0.304169E-06
		6	-0.583573E-06	7	0.294063E-06	8	-[illegible].293[illegible]93E-06				
COL	4	1	0.343464E-05	2	[illegible].868848E-05	3	0.128820E-07	4	[illegible].887584E-05	5	-0.214231E-05
		6	0.887267E-05	7	-0.398346E-05	8	[illegible].397557E-05				
COL	5	1	-0.601861E-06	2	-0.239596E-05	3	[illegible].156158E-07	4	-0.235713E-05	5	0.190561E-05
		6	-0.235821E-05	7	[illegible].17[illegible]7[illegible]7E-05	8	-0.168536E-05				
COL	6	1	0.298703E-05	2	[illegible].774645E-05	3	[illegible].106975E-07	4	0.774885E-05	5	-0.152885E-05
		6	0.775459E-05	7	-0.349301E-05	8	[illegible].349131E-05				
COL	7	1	-0.213064E-05	2	-0.597513E-05	3	-0.278937E-08	4	-0.597999E-05	5	0.257290E-05
		6	-0.598467E-05	7	0.388411E-05	8	-0.382496E-05				
COL	8	1	0.221501E-05	2	0.606043E-05	3	0.443801E-08	4	0.606555E-05	5	-0.226317E-05
		6	0.607129E-05	7	-0.359341E-05	8	0.359376E-05				

FIGURE III-L.22 DYNAMIC MATRIX, PORTAL FRAME

MATRIX KR PAGE 1

CUTOFF = 0.0 SIZE 8 BY 8

		ROW		ROW		ROW		ROW		ROW	
COL	1	1	0.182850E 06	2	-0.793242E 05	3	0.3695[illegible]2E 05	5	-0.468329E 05	6	0.258092E 04
		7	0.101617E 05	8	-0.305708E 04						
COL	2	1	-0.793242E 05	2	0.754484E 07	3	-0.277127E 05	4	-0.749955E 07	5	0.351247E 05
		6	-0.193569E 04	7	-0.762125E 04	8	0.229281E 04				
COL	3	1	0.365502E 05	2	-0.277126E 05	3	0.3793[illegible]2E 07	5	-0.701969E 05	6	0.709751E 04
		7	0.279447E 05	8	-0.840694E 04						
COL	4	2	-0.749955E 07	4	0.150000E 08	6	-0.749999E 07				
COL	5	1	-0.468329E 05	2	0.351247E 05	3	-0.701969E 05	5	0.140079E 06	6	-0.335519E 05
		7	-0.735083E 05	8	0.397419E 05						
COL	6	1	0.256092E 04	2	-0.193569E 04	3	0.709752E 04	4	-0.749959E 07	5	-0.335519E 05
		6	0.754012E 07	7	0.371232E 05	8	-0.583392E 05				
COL	7	1	0.101617E 05	2	-0.762125E 04	3	0.279447E 05	5	-0.735083E 05	6	0.371232E 05
		7	0.201494E 07	8	0.190424E 07						
COL	8	1	-0.305708E 04	2	0.229281E 04	3	-0.840694E 04	5	0.397419E 05	6	-0.583392E 05
		7	0.190424E 07	8	0.205739E 07						

FIGURE III-L.23 REDUCED CONDENSED STIFFNESS MATRIX, PORTAL FRAME

MATRIX MM PAGE 1

CUTOFF = [illegible] SIZE 8 BY 8

		ROW		ROW		ROW		ROW		ROW	
COL	1	1	0.914572E-01	2	[illegible].169580E-01	3	[illegible].294424E-02	5	0.721110E-02	6	-0.154836E-03
		7	-0.270339E-02	8	[illegible].992096E-03						
COL	2	1	0.165580E-01	2	[illegible].765787E-01	3	-[illegible].871294E-02	4	0.186336E-01	5	0.283627E-02
		6	-0.338225E-03	7	[illegible].238650E-03	8	-[illegible].13[illegible]895E-03				
COL	3	1	0.294423E-02	2	-[illegible].871298E-02	3	[illegible].114609E [illegible]	5	[illegible].145122E-01	6	-0.886994E-04
		7	-0.610707E-02	8	[illegible].205397E-02						
COL	4	2	0.186336E-01	4	[illegible].745342E-01	6	[illegible].186336E-01				
COL	5	1	0.721110E-02	2	0.283627E-02	3	[illegible].145122E-01	5	0.978232E-01	6	-0.361524E-02
		7	0.137635E-01	8	-[illegible].493078E-02						
COL	6	1	-0.154836E-03	2	-0.338225E-03	3	-[illegible].886990E-04	4	0.186336E-01	5	-0.361524E-02
		6	0.787368E-01	7	0.114252E-01	8	[illegible].109463E-01				
COL	7	1	-0.270339E-02	2	[illegible].238651E-03	3	-[illegible].610707E-02	5	0.137635E-01	6	0.114252E-01
		7	0.155109E 00	8	-[illegible].289341E-01						
COL	8	1	0.852056E-03	2	-[illegible].130895E-03	3	[illegible].205397E-02	5	-0.493078E-02	6	0.109463E-01
		7	-0.285341E-01	8	[illegible].114900E [illegible]						

$END

FIGURE III-L.24 REDUCED CONDENSED MASS MATRIX, PORTAL FRAME

SECTION IV

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APPENDIX I

MAGIC ERROR MESSAGES

The following is a list of all MAGIC error messages. The list is divided into three sections. The first section contains all Format error messages (Reference 6) and is divided into two parts, the preprocessor error message, and the execution error message. The second section contains error messages from all arithmetic and non-arithmetic modules developed to be used in conjunction with the structural generative module. The third section contains error messages generated by the structural generative system itself, which is the .USER04. module. In each section the error messages are in alphabetic order. The error message codes are significant in that the first six characters identify the subroutine from which the error message eminates. The occurrence of **** in the error message indicates that additional descriptive information will be supplied.

SECTION 1.   FORMAT ERROR MESSAGES

ALOC01 INSUFFICIENT STORAGE FOR ALLOCATION

The number of words of working storage available to the allocator is less than the minimum required for complete allocation of this job. This condition can be remedied by reducing the number of abstraction instructions.

ALOC02 INVALID NO. OF MASTER INPUT/OUTPUT DATA SETS SPECIFIED

The number of master input data sets and/or master output data sets specified on "INPUT TAPE" or "OUTPUT TAPE" cards is greater than the number of master input and/or master output data sets defined in the machine resources area as being available to FORMAT II. This condition can be remedied by reducing the number of "INPUT TAPE" and/or "OUTPUT TAPE" cards.

ALOC03 INSUFFICIENT UTILITY DATA SETS FOR ALLOCATION

The number of data sets with the FORMAT II system function IOUTIL is less than the minimum number required by the FORMAT II Preprocessor during the preprocessing phase. This condition can be remedied by reducing the number of "INPUT TAPE" or "OUTPUT TAPE" cards used in this job or by modifying the machine resources area. (i.e., define additional data sets with the FORMAT II system function IOUTIL.

ALOC04 MASTER OUTPUT DATA SET ****** SPECIFIED IN SAVE INSTRUCTION NOT DEFINED

A "SAVE" instruction in the abstraction instruction sequence refers to a master output data set name which has not been defined on an "OUTPUT TAPE" card. This condition can be remedied by including the appropriate "OUTPUT TAPE" card in the job.

ALOC05 MASTER INPUT DATA SET ****** HAS NOT BEEN MOUNTED

The FORMAT II allocator has not been able to locate a master input data set which has been specified on an "INPUT TAPE" card. This condition is usually caused by mounting the correct master input data set on the wrong unit or by misspelling the name of a properly mounted data set on the "INPUT TAPE" card.

ALOC06 MATRIX ****** IS NON-EXISTENT

A matrix, which appears in the abstraction instruction sequence and which has not been created in the abstraction instruction sequence prior to its use, has not been card input and does not appear on any master input data set. This condition can be remedied by inputting the required matrix.

ALOC07 DUPLICATE MATRICES ****** IN MATRIX DATA

Two or more matrices with the same name have been card input. This condition can be remedied by ensuring that all card input matrices have unique names.

ALOC08 CREATED MATRIX ****** IS CARD INPUT

A matrix which is created in the abstraction instruction sequence has the same name as a matrix which is card input. This condition can be remedied by removing the matrix in question from the card input matrix data.

ALOC09 SUBSCRIPTS OF ****** EXCEED DIMENSIONS OF MATRIX

The indices of a scalar element to be extracted from a matrix are larger than the dimensions of that matrix. This condition can be remedied by changing the indices of the scalar element specified in the abstraction instruction sequence.

ALOC10 DUPLICATE MATRICES CREATED -- NAME ******

A matrix in the abstraction instruction sequence appears more than once on the left side of an equal sign. This condition can be remedied by ensuring that all matrix names, which appear on the left side of an equal sign in the abstraction instruction sequence, have unique names.

ALOC11 MATRIX ****** IS USED MORE THAN ONCE IN INSTRUCTION ***

The matrix names appearing in the indicated instruction in the abstraction instruction sequence do not have unique names. This condition can be remedied by ensuring that all matrix names appearing in a given abstraction instruction have unique names.

ALOC12 CREATED MATRIX ****** HAS BEEN INPUT

A matrix which appears on the left side of an equal sign in the abstraction instruction sequence has the same name as a required input matrix. This condition can be remedied by either changing the name of the required input matrix or by changing the name of the matrix which appears on the left side of the equal sign.

ALOC13 MATRICES CREATED IN INSTRUCTION *** NEVER REFERENCED

The indicated abstraction instruction in the abstraction instruction sequence creates matrices, none of which are referenced in subsequent abstraction instructions. This condition can be remedied by removing the indicated abstraction instructions from the abstraction instruction sequence.

ALOC14 DUPLICATE STATEMENT NUMBERS ******

Duplicate statement numbers occur in the abstraction instruction sequence. This condition can be remedied by ensuring that each statement number occuring in the abstraction instruction sequence is unique.

ALOC15 GO TO DESTINATION ****** IS MISSING OR OCCURS BEFORE IF TEST

An abstraction instruction "IF" in the abstraction instruction sequence conditionally transfers to a non-existent statement number or transfers to a statement number on an abstraction instruction which is sequentially earlier than the "IF" abstraction instruction in question. This condition can be remedied by ensuring that all "IF" abstraction instructions conditionally transfer to a statement number which occurs sequentially after the "IF" abstraction instruction.

ALOC16 NON CONFORMABLE MATRICES IN INSTRUCTION ***

Two matrices occur in the indicated abstraction instruction in the abstraction instruction whose dimensions are such that the matrix operation in the indicated abstraction instruction is not defined.

EXEQ01 THE FORMAT SYSTEM IS UNABLE TO LOCATE MATRIX ******

This message signifies a malfunction of the user-coded subroutine which creates the specified matrix.

EXEQ02 CONFORMABILITY ERROR IN INSTRUCTION CREATING MATRIX ******

The matrices involved on the right side of the equals sign in the instruction creating the specified matrix are unconformable.

EXEQ03 MATRIX ****** IS SINGULAR

The matrix is singular in a "Solution of Equations" routine, i.e., in "STRCUT," "SEQEL" or "INVERS."

EXEQ04 AN ERROR HAS OCCURRED IN THE USER ** MODULE

An error recognized by the indicated user-coded subroutine has occurred. This will usually be associated with incorrect definition of the special data for use by thesubroutine.

EXEQ05 AN IMPROPER UPDATE HAS BEEN MADE TO THE FORMAT SYSTEM - EXECUTION TERMINATED

A new permanent module has not been properly incorporated. The FORMAT II systems analyst should be contacted if this error message occurs.

EXEQ05 AN ERROR HAS OCCURRED IN A USER-CODED MODULE, ERROR HAS BEEN WRITTEN BY MODULE

An error has occurred in a non-Format module. The specific error has been written by the subroutine in which the error was found.

EUTL3 THE SYSTEM IS UNABLE TO LOCATE A MATRIX. A TAPE SUMMARY OF LOGICAL UNIT **** WILL FOLLOW

The Format system is unable to locate a matrix. A tape summary of the data set on which the matrix should have been is printed out. The name of the matrix will appear in the next error message.

INST01 ILLEGAL OPTION SPECIFIED ON $INSTRUCTION CARD

An option other than "SOURCE" or "NOSOURCE" has been specified on the "$INSTRUCTION" card or a valid option starts before card column 16 in the "$INSTRUCTION" card.

INST02 INVALID STATEMENT NUMBER SPECIFIED

The statement number which is specified in card columns 1-5 of the abstraction instruction preceding this error message is composed of characters which are not all numeric.

INST03 INVALID CHARACTER IN COLUMN 6

Card column 6 of the abstraction instruction preceding this error message contains a character other than a blank or zero.

INST04 UNRECOGNIZABLE OPERATION CODE

The operation specified in the abstraction instruction preceding this error message is not contained in the FORMAT II library of valid operations.

INST04 SYNTAX ERROR IN - GPRINT - INSTRUCTION

INST04 ILLEGAL NEGATIVE INPUT VALUE FOR SUPPRESSION OF MATRIX ELEMENTS, ABSOLUTE VALUE TAKEN

The effective zero value for suppression of element print in the GPRINT instruction must be positive.

INST04 INVALID SPECIFICATION OF INPUT MATRICES

An incorrect number of input matrices has been specified in the GPRINT instruction.

INST04 ILLEGAL SPECIFICATION OF COLUMN HEADERS

Incorrect syntax in GPRINT when written column headers.

INST05 SYNTAX ERROR IN - IF - INSTRUCTION

The abstraction instruction "IF" which precedes this error message contains an unrecognizable field.

INST05 SYNTAX ERROR IN - EPRINT - INSTRUCTION

INST05 INVALID PRINT CONTROL

The print control in the EPRINT instruction was incorrectly specified.

INST05 ILLEGAL NEGATIVE INPUT VALUE FOR SUPPRESSION OF MATRIX ELEMENTS, ABSOLUTE VALUE TAKEN

The effective zero value for suppression of element print in the EPRINT INSTRUCTION must be position.

INST05 ILLEGAL SUPPRESSION OF PARAMETER

The code indicating either stress or force matrices to be printed has been omitted.

INST06 SYNTAX ERROR IN - PRINT - INSTRUCTION

The abstraction instruction "PRINT" which precedes this error message contains an unrecognizable field.

INST07 SYNTAX ERROR IN - SAVE - INSTRUCTION

The abstraction instruction "SAVE" which precedes this error message contains an unrecognizable field.

INST08 OPERATION CODE NOT INCLOSED BY PERIODS

The operation code in the abstraction instruction preceding this error message is not inclosed by periods.

INST09 SYNTAX ERROR IN ARITHMETIC INSTRUCTION

The arithmetic abstraction instruction preceding this error message contains an unrecognizable field.

INST10 THIS INSTRUCTION IS NOT AVAILABLE

An incomplete modification to the instruction card processor area has been made. The FORMAT II systems analyst should be notified immediately.

INST43 INVALID SPECIFICATION OF PARAMETERS

A syntax error has occurred in the DEJOIN instruction.

INST43 - INVALID INDEX SPECIFIED

Parameter specifying row or column dejoin is illegal.

INST43 INVALID MATRIX NAME

The DEJOIN instruction contains one invalid matrix name.

MATR01 UNRECOGNIZABLE OPTIONS ON $MATRIX CARD STANDARD OPTIONS USED WARNING ONLY

An option other than "LIST", "NOLIST", "PRINT" or "NOPRINT" has been specified on the "$MATRIX" card or a valid option starts before column 16 on the "$MATRIX" card.

MATR02 CARD FOLLOWING $MATRIX CONTROL CARD IS NOT A HEADER CARD OR HAS - H - MISSING IN COLUMN 1

The first card following the "$MATRIX" card must be the header card of the first card input matrix. All data up to the first header card will be ignored.

MATR03 NAME ON DATA CARD IS DIFFERENT FROM NAME ON HEADER CARD. THIS MATRIX WILL BE IGNORED

The matrix header card and all associated matrix data must have the same name in card columns 67-72.

MATR04 ROW AND/OR COLUMN VALUE EXCEED MATRIX SIZE, IS NEGATIVE OR IS ZERO AND VALUE IS NONZERO. THIS MATRIX WILL BE IGNORED.

An element specified in the matrix card input data is outside the dimensions of the matrix, of which it is supposed to be an element.

MATR05 MATRIX EXCEEDS ALLOTTED STORAGE. THIS MATRIX WILL BE IGNORED.

The number of words of working storage available to the matrix card reader module is less than the number of words necessary to contain all the nonzero elements in one of the card input matrices. The number of words of working storage required for a given matrix is approximately three (3) times the number of nonzero elements in the matrix. This condition can be remedied by decreasing the number of nonzero elements in the card input matrix.

MATR06 DUPLICATE I-J VALUES ENCOUNTERED. THIS MATRIX WILL BE IGNORED. I = **** J = ****

Two or more values have been specified for the same matrix element in the matrix card input data. This condition can be remedied by ensuring that each matrix element has a unique set of I - J values.

MATR07 I VALUE ON HEADER CARD EXCEEDS ALLOTTED SIZE OR IS LESS THAN OR EQUAL TO ZERO. THIS MATRIX WILL BE IGNORED.

The number of rows specified in the header card of a card input matrix is greater than the maximum number of rows permitted in a matrix which is processed by the FORMAT II system, or is less than or equal to zero. This condition can be remedied by reducing the dimensions of the card input matrix.

MATR08 J VALUE ON HEADER CARD EXCEEDS ALLOTTED SIZE OR IS LESS THAN OR EQUAL TO ZERO. THIS MATRIX WILL BE IGNORED.

The number of columns specified in the header card of a card input matrix is greater than the maximum number of columns permitted in a matrix which is processed by the FORMAT II system, or is less than or equal to zero. This condition can be remedied by reducing the dimensions of the matrix.

MATR09 FIRST CHARACTER OF MATRIX NAME ON HEADER MUST BE ALPHABETIC. THIS MATRIX WILL BE IGNORED.

The matrix name which is to be given to a set of matrix card input data and which is punched in card column 67-72 of the header card and all associated data cards must follow the rules for valid matrix names as defined for the FORMAT II system. The rule which applies in this case is that the first character of a matrix name must be alphabetic.

MATR10 ILLEGAL CARD ENCOUNTERED. FOLLOWING CARDS IGNORED UNTIL ANOTHER - $ - CONTROL CARD IS FOUND.

A card has been encountered in the matrix card input data which has an illegal character punched in card column 1. The only valid characters which may appear in card column 1 are "H", "E", and blank.

MATR11 CARD FOLLOWING E CARD IS NOT A $ CONTROL CARD - WARNING ONLY.

In a valid FORMAT II deck setup the only cards which may follow the "E" card which is the last card in the matrix card input data, are the "$SPECIAL" card and the "$END" card.

MRES01 FIRST CARD IS NOT A - $ - CONTROL CARD

The first card of all FORMAT II jobs must be a "$MAGIC" or a "$FORMAT" card.

MRES02 FIRST - $ - CONTROL CARD IS NOT A $MAGIC CARD. ALLOCATION SUPPRESSED

The first card of all FORMAT II jobs must be a "$MAGIC" or a "$FORMAT" card.

MRES03 UNRECOGNIZABLE OPTION ON - $MAGIC CARD STANDARD OPTION ASSUMED

An option other than "NEW", "STANDARD" (or blank) or "CHANGE" has been specified on the "$MAGIC" card or a valid option starts before column 16 on the "$MAGIC" card.

MRES04 ILLEGAL CARD FOR - CHANGE - OPTION - ALLOCATION SUPPRESSED

The "DELETE" card and the "UPDATE" card are the only valid machine resources data cards which are valid when the "CHANGE" option has been specified on the "$FORMAT" card. The "SETUP" card is the only valid machine resources data card which is valid when the "NEW" option has been specified on the "$FORMAT" card.

MRES05 THE SYSTEM INPUT DATA SET OR OUTPUT DATA SET HAS BEEN SPECIFIED AS A FORMAT II SYSTEM FUNCTION

Two Fortran logical data sets which must not be specified on "UPDATE", "DELETE", or "SETUP" cards are the system input data set and the system output data set.

MRES06 DUPLICATE DATA SETS SPECIFIED - ALLOCATION SUPPRESSED

A Fortran logical data set has been specified more than once on "SETUP" or "UPDATE" cards.

MRES07 INVALID **** VALUE DETECTED ALLOCATION SUPPRESSED

An invalid field has been specified on an "UPDATE" or "SETUP" card. The valid fields are as follows. The first field must contain the logical data set number (an integer). The second field a valid FORMAT II system function (e.g., "MASTRI", "MASTRO", or "IOUTIL"). The third field must contain the physical device containing the data set. The valid specifications in the field are "TAPE", "DISK", "DRUM", or "CELL". The fourth field must contain the logical channel designation. This consists of a letter A to H. The fifth field must contain the capacity of the data set in basic machine units (e.g., bytes, etc.). This field must be an integer number. The error message indicates which of the five fields is in error.

MRES08 INCORRECT SETUP OR UPDATE CARD ALLOCATION SUPPRESSED

A missing field has been detected on a "SETUP" or "UPDATE" card.

MRES09 INSUFFICIENT I/O UTILITY DATA SETS - ALLOCATION SUPPRESSED

A minimum number of Fortran logical data sets available to FORMAT II must have the FORMAT II system function of "IOUTIL". The FORMAT II preprocessor selects several of the data sets with this function for scratch data sets during preprocessing. This condition can be remedied by specifying additional data sets on "SETUP" or "UPDATE" cards with the FORMAT II system function "IOUTIL".

MRES10 ILLEGAL DEVICE SPECIFIED FOR MASTER INPUT DATA SET

The only valid device types which may be specified for a FORMAT II data set whose system function is "MASTRI" are "TAPE" and "DISK". A "SETUP" or "UPDATE" card is the source of the error.

MRES11 ILLEGAL DEVICE SPECIFIED FOR MASTER OUTPUT DATA SET

The only valid device types which may be specified for a FORMAT II data set whose system function is "MASTRO" are "TAPE" and "DISK". A "SETUP" or "UPDATE" card is the source of the error.

PREP01 INVALID CONTROL CARD OR INCORRECT DECK SETUP

The FORMAT II preprocessor has encountered a control card which is unrecognizable or which is valid but does not occur in its proper place. Recommended corrective action is to check the spelling of all control cards and check the deck set up.

PREP02 NOT A - $ - CONTROL CARD. CARD IGNORED

When an invalid control card is encountered or incorrect deck setup is recognized, the preprocessor searches for the next "$" control card.

PREP03 PREPROCESSING TERMINATED EXECUTION HALTED

Whenever a serious error occurs the preprocessing is terminated and a "NOGO" condition is established.

PROB01 UNRECOGNIZABLE OPTION ON - $RUN - CARD. STANDARD OPTION USED.

An option other than "GO", "NOGO", "LOGIC" or "NOLOGIC" has been specified on the "$RUN" card or a valid option starts before column 16 in the "$RUN" card.

PROB02 CONTRADICTORY EXECUTION OPTIONS - ALLOCATION SUPPRESSED

The options "GO" and "NOGO" have been specified on the "$RUN" card.

PROB03 CONTRADICTORY LGOIC OPTIONS - ALLOCATION SUPPRESSED

The options "LOGIC" and "NOLOGIC" have been specified on the "$RUN" card.

PROB04 MISSING LEFT PARENTHESIS - ALLOCATION SUPPRESSED

A problem specification data card has a missing left parenthesis.

PROB05 UNRECOGNIZABLE CARD

A problem specification data card is unrecognizable. The valid problem specification data cards are the "ANALYSIS" card, the "PROBLEM" card, the "PAGE SIZE" card, the "INPUT TAPE" card, and the "OUTPUT TAPE" card.

PROB06 MISSING COMMA ON MASTER I/O TAPE CARD - ALLOCATION SUPPRESSED

There is a missing field on an "INPUT TAPE" card or on an "OUTPUT TAPE" card in the problem specification data.

PROB07 ILLEGAL MASTER I/O DATA SET NAME - ALLOCATION SUPPRESSED

The master input or master output data set name which has been specified on "INPUT TAPE" card or on "OUTPUT TAPE" card in the problem specification data is invalid. Master Input/Output data set names follow the same rules as matrix names. In particular, the name must be 1-6 characters long and the first character must be alphabetic.

PROB08 ILLEGAL INTEGER ON MASTER I/O TAPE CARD

The second field of an "INPUT TAPE" or "OUTPUT TAPE" card in the problem specification data is not an integer number.

PROB09 ILLEGAL PAGE SIZE - ALLOCATION SUPPRESSED

An invalid page size has been specified on the "PAGE SIZE" card in the problem specification data. The valid page sizes are "11 * 8", "8 * 11" and "14 * 11".

PROB10 MASTER INPUT OR OUTPUT DATA SET USED PREVIOUSLY

All master input and output data set names as specified on "INPUT TAPE" and "OUTPUT TAPE" cards in the problem specification data must be unique.

PROB11 INVALID SIZE SPECIFIED ON SIZE CARD

An integer number must be specified in the only field of the "SIZE" card.

SECTION 2. MISCELLANEOUS ARITHMETIC MODULE ERROR MESSAGE

ASSEM - The order of the assembled - unreduced system, NSYS = *****, the maximum size system can only = ***** D.O.F.

The variable KONST in subroutine MRES must be updated to allow the user to assemble a system with NSYS degrees of freedom.

ASSEMC - Element number *****, generated a LISTEL value of *****, while NSYS = *****.

If this error occurs see the MAGIC system analyst.

ASSEMS - Must update the dimension of the list and format arrays to allow for ***** degrees of freedom.

The dimension of two arrays in subroutine ASSEMS must be updated to assemble more degrees of freedom than allowed. If this error occurs see the MAGIC system analyst.

COLREP - Input matrix ****** exceeds allowable size IMAX = *****.

The number of rows of the input matrix exceeds the value of KONST. IMAX is the number of rows in the input matrix.

DEJNC - The partition number = *****, is greater than or equal to the column dimension = ***** of the input matrix.

An invalid column partition number has been specified in the DEJOIN instruction 1 $\leq$ JPART < ICOL.

DEJNR - The partition number = *****, is greater than or equal to the row dimension = ***** of the input matrix.

An invalid row partition number has been specified in the DEJOIN instruction 1 $\leq$ JPART < IROW.

DEJOIN - Invalid partition number = *****

The matrix partition number must be greater than one.

EPRINT - Unable to execute the EPRINT module. The work array is not long enough for execution.

The variable NWORK in subroutine MRES must be updated for more work storage.

EPRINT - The element information is for element number **** - go to next element.

Unable to print out stresses or forces for this element, continue execution. If this error occurs contact the MAGIC system analyst

EPRINT - The number of elements in the input matrices are not the same.

If this error occurs contact the MAGIC system analyst.

EPRINT - Printing for element type *****, are not available, proceeding to next element.

The EPRINT module has not been updated to handle this element type. Contact the MAGIC system analyst.

FORCE1 - Unable to execute the force module. The work array contains ******** words, and ******** words are needed to process the maximum element.

There is not enough work storage to calculate the forces for all elements. The variable NWORK must be updated in subroutine MRES.

FORCE2 - Forces for element type *****, are not available, proceeding to next element.

The FORCE module has not been updated to handle this element type. The MAGIC system analyst should be contacted if this error occurs.

FREEUP - The number of matrices to be kept was input as MATOUT = ******, the number of non-zero elements of MAT = ****.

If this error should occur contact the MAGIC system analyst.

GPRNT1 - The row dimension of TR(transformation matrix for application of boundary conditions) = ******. The number of columns of TR = ******. This should equal row dimension.

An incorrect matrix was input in the ·GPRINT· instruction.

GPRNT1 - The analyst has asked for ***** eigenvalues to be printed. Subroutine GPRINT allows a maximum of ***** values to be printed - see a program analyst to correct this error.

Subroutine GPRINT must be updated to allow more eigenvalues to be printed.

GPRNT1 - Error while processing matrix ******.

An error has occurred in the GPRINT instruction while processing matrix named.

GPRNT1 - The matrix to be printed has ****** rows while TR indicates that it should have ****** rows.

The input matrix to be printed is incorrect or the input transformation matrix is incorrect.

GPRNT1 - Eigenvector matrix has ***** eigenvectors, while the eigenvalue matrix has ***** eigenvalues.

The eigenvector and eigenvalue matrices input into the GPRINT instruction are not compatable.

STRES1 - Unable to execute the STRESS module. The work array contains ******** words, and ******** words are needed to process the maximum element.

There is not enough work storage to calculate the stresses for all elements. The variable NWORK must be updated in subroutine MRES.

STRES2 - Stresses for element type *****, are not available proceeding to next element.

The STRESS module has not been updated to handle this element type. The MAGIC system analyst should be contacted if this error message occurs.

SECTION 3. .USER04. ERROR MESSAGES

CHEK - Input section **** has not been found. This input section is required for generation of the following matrices.

The named matrices cannot be generated due to the omission of the specified input section.

CONTRL - System information card missing. Cannot allocate storage.

All input data decks must have SYSTEM section to allocate storage for processing of input.

CONTRL - System information card missing. Cannot allocate storage.

The SYSTEM card is missing from the report form input deck.

CONTRL - $END card encountered while reading .USER04. input, indicating absence of end or check card. Check card will be inserted.

END or CHECK card missing from report form input deck.

DEFLEX - .USER04. Module unable to locate matrix ******.

The system is unable to locate a matrix.

DEFLEX - Matrix ****** does not qualify as an input displacement matrix for the .USER04. module. Dimensions are ***** by ***** and should be ***** by *****.

The input displacement matrix used to calculate incrementals is of the wrong order.

DEFLEX - Matrix ****** does not qualify as an input displacement or stress matrix.

The input matrix used to calculate incrementals is of the wrong order. If the matrix was a stress matrix then it must have been generated using the .STRESS. abstraction instruction.

ELEM - Element control error in subroutine ELEM. Element number ***** calls plug number ***. Plug number should be greater than zero. Execution terminated.

All element type code numbers are greater than zero. Proper element type cannot be selected.

ELEM - Element control error in subroutine ELEM. Element number ***** has material number ******. Material identification must be different from zero. Execution terminated.

Self-explanatory.

ELEM - Element control error in subroutine ELEM. Element number ***** has number of grid points = ***. Number of grid points must be greater than zero and no greater than eight. Execution terminated.

Self explanatory.

ELPLUG - Element input error No. *. Plug No *. Element No. ****.

Error number 1 - incorrect plug number (element type code)
Error number 2 - incorrect number of element defining points
Error number 3 - incorrect value for extra element input indicator
Error number 4 - incorrect matrix orders for element (number of degrees of freedom per point incorrect)

ELEM - Element control error in subroutine ELEM. Element number ***** has number of input points = **. Number of input points must be position. Execution terminated.

Self-explanatory.

ELEM - Input error in subroutine ELEM. Element node point is negative or zero in element number *****.

No element defining point number may be negative and only mid-points may be zero.

ELEM - Input error in subroutine ELEM, after interpolation value of Young's Modulus equals +.******** + ** in material number ******, ************************. Value should be greater than 1.0. Execution terminated.

Self-explanatory.

ELEM - Input error in subroutine ELEM, after interpolation Poisson value equals +.********E + ** in material number ******, ************************. Value should be greater than -1.0 and less than 1.0. Execution terminated.

Self-explanatory.

ELEM - Input error in subroutine ELEM, after interpolation thermal coefficient values equals +.********E + ** in material number ******, ************************. Value should be greater than -1.0 and less than 1.0. Execution terminated.

Self-explanatory.

ELEM - Input error in subroutine ELEM, after interpolation rigidity value equals + .********E + ** in material number ******, ************************. Value should be greater than 1.0. Execution terminated.

Self-explanatory.

ELEM - Input error in subroutine ELEM. Mass density value equals + . XXXXXXXXE + ** in material number ******, ************************. Value should be greater than zero. Execution terminated.

Self-explanatory.

ELEM - Input error in subroutine ELEM. Value of IP = ***, value of IPRE = *** for element number one. Request to repeat data from element previous to first element is illogical. Execution terminated.

IP and IPRE cannot be negative for first element.

ELEM - Input error in subroutine ELEM. Element number ****** is defined by node points for which no coordinates have been input. Calculation of material temperature impossible. Execution terminated.

Self explanatory.

ELEM - Cannot locate material library.

The system cannot locate the material library matrix.

ELEM - Material error in subroutine ELEM. Material number ****** was not located on material tape. Execution terminated.

The specified material number was not available in the material library.

ELPLUG - Element input error no. ****, Plug No. ****, and Element No. ****.

An error has occurred in generation of specified element.
Error No. = 1 Plug number (element type) incorrect
Error No. = 2 Number of nodes incorrect
Error No. = 3 Number of input element cards incorrect.

FMAT - Input error in subroutine FMAT. Material number ******, ************************. Number of material temperature points is **. Number of plastic temperature points is **. Number of temperature points in either case cannot exceed 9. Execution terminated.

Self explanatory.

FMAT - Input error in Subroutine FMAT. Mass density value equals ±******** ± ** in material number ****, ************************. Value should be non-negative. Execution terminated.

Self-explanatory.

FMAT - Input error in subroutine FMAT. Poisson value equals ± .******** ± ** in material number ******, ************************. Value should be greater than -1.0 and less than 1.0. Execution terminated.

Self-explanatory.

FMAT - Input error in subroutine FMAT. Rigidity value equals ± .*********E ± ** in material number ******, ************************. Value should be greater than 1.0. Execution terminated.

Self-explanatory.

FMAT = Input error in subroutine FMAT. Thermal coefficient value equals ± .*********E ± ** in material number ******, ************************. Value should be greater than -1.0 and less than 1.0. Execution terminated.

Self-explanatory.

FMAT - Input error in subroutine FMAT. Value of Young's modulus equals ± .*********E ± ** in material number ******, ************************. Value should be greater than 1.0.

Self-explanatory.

FMAT - Error message from subroutine FMAT. Attempt to delete material number ****** using lock code **. Incorrect lock code, request ignored

Self-explanatory.

FMAT - Error message from subroutine FMAT. Attempt to delete material that was not on material tape. Material number ******. Material identification is ************************. Input code is ***. Request ignored.

Self-explanatory.

FMAT - Error message from subroutine FMAT. Attempt to revise material number ****** using lock code **. Input lock code does not match tape lock code for this material. Revisions or deletions not allowed without proper lock code. Execution terminated.

Self-explanatory.

FMAT - Error message from subroutine FMAT. Additions requested exceed capacity of material tape. Maximum number of materials cannot exceed ***.

Self-explanatory.

FMAT - Error message from subroutine FMAT. Request for print of material that was not on tape. Material number ******. Material identification is ************************. Input code is ***. Request ignored.

Self-explanatory.

FMAT - Error message from subroutine FMAT. Unrecognizable data input code. Legal codes are PI, PO, I. O, P, OUT, ALL, SEE, SUM. Material number ******. Material identification is ************************. Input code is ***. Execution terminated.

Self-explanatory.

FMAT - Error message from subroutine FMAT. Number of requests received is zero.

Number of requests must not be zero. Value of zero indicates improper operation of program.

FMAT - Error message from subroutine FMAT. Attempt to input plastic data only for material which was not on tape. Material number ******. Material identification is ************************. Input code is ***. Request ignored.

Usage of an input code of "P" requires that the material to be revised already exists in the material library.

FMAT - New material tape not generated. All revisions and/or deletions requested by this case have been ignored.

Due to a previous error, generation of a new material library has been abandoned. Execution will be terminated.

FORMIN - Unexpected label card read - point *****.

Input section label card encountered while reading table form input. Point reflects entry now being processed.

FORMIN - Repeat for first point ignored.

Repeat option on table forms of report form input cannot be used for first value entered.

FRED - There is a mistake in the coordinates for this transformation, we will calculate the remaining in spite of this.

An error has occurred in generating a grid point axes transformation matrix. Execution will continue.

F6211 - The integral of (LN(A+B*X)/X) DX is not allowed for A+B*X=0. A = +.******E + **., B = ± .*******E ± **, X = ± .*******E ± **

Natural log of zero is undefined.

INDECK - .USER04. input matrix ****** is not a valid deck (word count error).

The specified matrix does not qualify as a valid interpreted input deck.

INDECK - .USER04. input matrix ****** is not a valid deck (compression error).

The specified matrix does not qualify as a valid interpreted input deck.

INPUT - Input error, number of directions of grid points not equal to number of directions of transformation matrix. Execution terminated.

Order of grid point axes transformation matrices must be equal to three.

INPUT - Input error, number of reference points input exceeds ****.

Program cannot accommodate more than the given number of input points.

INPUT - Label card error ******.

Input card read should have been label card. Execution will be terminated.

LOGFLO - Logical input error - matrix ****** cannot be generated by .USER04. module due to suppression of fourth input matrix. Execution phase suppressed. Input processing continuing.

The incremental matrices cannot be generated because the input displacement or stress matrix has been suppressed.

PDISP - Input section ****** matrix not generated due to prescribed displacement conditions .NE. 1 and .LT. Load conditions input.

The Prescribed Displacement matrix has not been generated because of an illegal combination of external load conditions and prescribed displacement conditions.

PHASE1 - Unexpected blank label card encountered.

Card read should have contained an input section label. Input processor will attempt to continue.

PHASE1 - No option has been selected for request number *** of material library.

Self-explanatory.

PHASE1 - More than one option has been selected for request number *** of material library. Only the first selection will be retained.

Self-explanatory.

PHASE1 - Maximum number of load conditions allowed is 100. This problem contains ****.

Self-explanatory.

PHASE1 - Load condition *** sub-label is incorrect. Program cannot distinguish between load conditions.

Load condition sub-label in report form input is in error.

PHASE1 - Illegal MODAL card encountered. Card will be ignored.

A MODAL card has been found while reading an input section for which no MODAL card has been defined.

PHASE1 - Due to previously encountered error condition this section is being skipped. Program will flush data deck until next recognizable input section is encountered.

PHASE1	-	Unrecognizable input section. Input section label has been read which is undefined in input processor.
PHASE1	-	Due to above error message this section will be omitted and check card inserted. Self-explanatory.
PHASE2	-	Number of entries read for this section, *****, does not agree with number that was to be read, *****. Actual number read will be used. Self-explanatory.
PHASE2	-	This section has either been omitted or flushed by phase one error. In either case this section is considered critical and execution will not be allowed. Self-explanatory.
PHASE2	-	Due to the omission of this section the following sections may be ignored - ****** ****** ****** ... The final processing of certain sections requires data from other sections which by omission or other input error are not present.
PHASE2	-	This section is to be merged with ****** and ****** for which values have been assigned by both for point number *****. Two values cannot be assigned to the same point. Neither value will be used. Self-explanatory.
PHASE2	-	This section is to be merged with ****** and ****** for which modal cards have been encountered for both. Two values cannot be assigned to the same point. Both modal cards will be ignored. Self-explanatory.
PHASE2	-	Number of elements read ***** is greater than 9999. Number of elements will be set at 9999. Self explanatory, execution will be suppressed.

PHASE2 - No end or check card has been found. Check card will be inserted, suppressing execution.

Self-explanatory.

PHASE2 - Due to above error condition check card will be inserted. Execution will be suppressed.

Self-explanatory.

PHASE2 - Internal tape error has occurred. Processing abandoned.

Report form input preprocessor cannot retrieve information stored on a scratch data set.

PLUG1 - Value of sin (alpha) is zero - run terminated.

Element defining points are in error for Quadrilateral Thin Shell Element.

PLUG5 - For I = XX and N = XX integral does not converge.

No convergence has been obtained for the given integral calculated by the Romberg technique in the Toroidal Ring Element.

PLUG5 - Maximum number of iterations reached in Romberg integration routine.

Convergence was not obtained in 15 iterations for an integral in the toroidal thin shell element. Processing will continue, using 15 iteration result.

PRINT5 - Toroidal ring element with coordinates
R1 = ± .*********E ± **, R2 = ± .*********E ± **,
Z1 = ± .*********E ± **, Z2 = ± .********* ± **
is not diagonally dominant and should be subdivided.

Element stiffness matrices must be diagonally dominant.

P7PRT - PLUG7 error - third point to define plane was not given - input error.

Three element defining points are required for the frame element, the third supplying definition of the plane.

TRAIC	-	Subroutine MINV has determined array GAMABQ to be singular, execution terminated by subroutine TRAIC.
		Transformation matrix to system coordinates in triangular cross-section ring element cannot be inverted, usually because three element defining points do not define a triangle.
US04A	-	Available scratch data sets **** is less than the required 4.
		The .USER04. module requires at least four scratch data sets. The addition of more data sets is required by the program.
US04A	-	Input routine, core storage required ****** exceeds that available ****** to displacement method matrix generator.
		Blank common work area is not large enough for processing input.
US04A	-	Report routine core storage required ****** exceeds that available ****** to displacement method matrix generator.
		Blank common work area is not large enough for processing report form input data.
US04A	-	Grid point loads matrix storage required ****** exceeds that available ****** to displacement method matrix generator.
		Blank common work area is not large enough for generation of grid point loads matrix.
US04A	-	Reduction of transformation matrixes storage ****** exceeds that available to displacement method matrix generator.
		Blank common work area is not large enough for generation of reduction transformation matrix.
US04A	-	Element generation core storage required ****** exceeds that available ****** to displacement method matrix generator.
		Blank common work area is not large enough for generation of element matrices.

USO4A - Assembly transformation matrix size ****** exceeds limit ****** of MAGIC system.

Self-explanatory.

USO4A - Grid point load matrix size ****** exceeds limit ****** of MAGIC system.

Self-explanatory.

USO4A - Reduction transformation matrix size ****** exceeds limit ****** of MAGIC system.

Self-explanatory.

USO4A - Stiffness matrix size ****** exceeds limit of MAGIC system.

Self-explanatory.

USO4A - Stress matrix size ****** exceeds limit ****** of MAGIC system.

Self-explanatory.

USO4A - Number elements size ****** exceeds limit ****** of MAGIC system.

Self-explanatory.

USO4A - Output matrix ****** will be a duplicate of input matrix ******.

The user is saving the interpreted input deck when he already has an interpreted input matrix.

USO4B - Element sort routine core storage required ****** exceeds that available ****** to displacement method matrix generator.

Blank common work area is not large enough for output of generated matrices.